2017 Stock Assessment and Fishery Evaluation Report for the Pribilof Islands Blue King Crab Fisheries of the Bering Sea and Aleutian Islands Regions

William T. Stockhausen

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Executive Summary

1. *Stock:* Pribilof Islands blue king crab (PIBKC), *Paralithodes platypus.*
2. *Catches:* Retained catches have not occurred since 1998/1999. Bycatch has been relatively small in recent years. No bycatch mortality was observed in 2016/17 in the crab (e.g., Tanner crab, snow crab) fisheries that incidentally take PIBKC. Bycatch mortality for PIBKC in these

fisheries was 0.166 t (0.0004 million lbs) in 2015/16, but this was the first non-zero bycatch mortality in other crab fisheries since 2010/11. Most bycatch mortality for PIBKC occurs in the BSAI groundfish fixed gear (pot and hook-and-line) fisheries (5-year average: 0.048 t) and trawl fisheries (5-year average: 0.309 t). In 2016/17, the estimated PIBKC bycatch mortality was 0.018 t in the groundfish fixed gear fisheries and 0.364 t in the groundfish trawl fisheries.

3. *Stock biomass:* Stock biomass decreased between the 1995 and 2008 surveys, and continues to fluctuate at low abundances in all size classes. Any short-term trends are questionable given the high uncertainty associated with recent survey results.

4. *Recruitment:* Recruitment indices are not well understood for Pribilof Islands blue king crab. Pre-recruits may not be well-assessed by the survey, but have remained consistently low in the past 10 years.

5. *Management performance:* The stock is below MSST and consequently is overfished. Overfishing did not occur. The following results are based on determining B_{MSY}/MSST by averaging the MMB-at-mating time series estimated using the smoothed survey data from a random effects model; the current (2017/18) MMB-at-mating is also based on the smoothed survey data. [Note: MSST changed substantially between 2013/14 and 2014/15 as a result of changes to the NMFS EBS trawl survey dataset used to calculate the proxy B_{MSY}. MSST has changed slightly since 2014/15 due to small differences in the random effects model results with the addition of each new year of survey data.]

Table 1: Management performance, all units in metric tons. The OFL is a total catch OFL for each year.

Year	MSST	Biomass (MMB_{mating})	TAC	Retained Catch	Total Catch Mortality	OFL	ABC
2013/14	2,001 A	225 A	closed	0	0.03	1.16	1.04
2014/15	2,055 A	344 A	closed	0	0.07	1.16	0.87
2015/16	2,058 A	361 A	closed	0	1.18	1.16	0.87
2016/17	2,054 A	233 A	closed	0	0.38	1.16	0.87
2017/18	--	230 B	--	--	--	1.16	0.87

Notes:

A – Based on data available to the Crab Plan Team at the time of the assessment following the end of the crab fishing year.

B – Based on data available to the Crab Plan Team at the time of the assessment for the crab fishing year.

Table 2: Management performance, all units in the table are million pounds.

Year	MSST	Biomass (MMB_{mating})	TAC	Retained Catch	Total Catch Mortality	OFL	ABC
2013/14	4.411 A	0.496 A	closed	0	0.0001	0.0026	0.002
2014/15	4.531 A	0.758 A	closed	0	0.0002	0.0026	0.002
2015/16	4.537 A	0.796 A	closed	0	0.0026	0.0026	0.002
2016/17	4.528 A	0.514 A	closed	0	0.0008	0.0026	0.002
2017/18	--	0.507 A	--	--	--	0.0026	0.002

6. *Basis for the 2017/18 OFL:* The OFL was based on Tier 4 considerations. The ratio of estimated 2016/17 MMB-at-mating to B_{MSY} is less than β (0.25) for the F_{OFL} Control Rule, so directed fishing is not allowed. As per the rebuilding plan (NPFMC, 2014a), the OFL is based on a Tier 5 calculation of average bycatch mortalities between 1999/2000 and 2005/2006, which is a time period thought to adequately reflect the conservation needs associated with this stock and to acknowledge existing non-directed catch mortality. Using this approach, the OFL was determined to be 1.16 t for 2017/18. The following results are based on determining B_{MSY}/MSST by averaging the MMB-at-mating time series estimated using the smoothed survey data from a random effects model; the current (2017/18) MMB-at-mating is also based on the smoothed survey data.

Table 3: Management performance, all units in metric tons. The OFL is a total catch OFL for each year.

Year	Tier	B_{MSY}	Current MMB_{mating}	B/B_{MSY} (MMB_{mating})	γ	Years to define B_{MSY}	Natural Mortality	P*
2013/14	4c	3,988	278	0.07	1	1980/81-1984/85 &1990/91-1997/98	0.18	10% buffer
2014/15	4c	4,002	218	0.05	1	1980/81-1984/85 &1990/91-1997/98	0.18	25% buffer
2015/16	4c	4,109	361	0.09	1	1980/81-1984/85 &1990/91-1997/98	0.18	25% buffer
2016/17	4c	4,116	233	0.06	1	1980/81-1984/85 &1990/91-1997/98	0.18	25% buffer
2017/18	4c	4,108	230	0.06	1	1980/81-1984/85 &1990/91-1997/98	0.18	25% buffer

Table 4: Management performance, all units in the table are million pounds.

Year	Tier	B_{MSY}	Current MMB_{mating}	B/B_{MSY} (MMB_{mating})	γ	Years to define B_{MSY}	Natural Mortality	P*
2013/14	4c	8.79	0.613	0.07	1	1980/81-1984/85 &1990/91-1997/98	0.18	10% buffer
2014/15	4c	8.82	0.481	0.05	1	1980/81-1984/85 &1990/91-1997/98	0.18	10% buffer
2015/16	4c	9.06	0.795	0.09	1	1980/81-1984/85 &1990/91-1997/98	0.18	25% buffer
2016/17	4c	9.07	0.514	0.06	1	1980/81-1984/85 &1990/91-1997/98	0.18	25% buffer
2017/18	4c	9.06	0.507	0.06	1	1980/81-1984/85 &1990/91-1997/98	0.18	25% buffer

7. *Probability density function for the OFL:* Not applicable for this stock.

8. *ABC:* The ABC was calculated using a 25% buffer on the OFL, as in the previous assessments since 2015. The ABC is thus 0.87 t (= 0.25x1.16 t).

9. *Rebuilding analyses results summary:* In 2009, NMFS determined that the PIBKC stock was not rebuilding in a timely manner and would not meet a rebuilding horizon of 2014. A preliminary assessment model developed by NMFS (not used in this assessment) suggested that rebuilding could occur within 50 years due to random recruitment (NPFMC, 2014a). Subsequently, Amendment 43 to the King and Tanner Crab Fishery Management Plan (Crab

FMP) and Amendment 103 to the Bering Sea and Aleutian Islands Groundfish FMP (BSAI Groundfish FMP) to rebuild the PIBKC stock were adopted by the Council in 2012 and approved by the Secretary of Commerce in early 2015. The function of these amendments is to promote bycatch reduction on PIBKC by closing the Pribilof Islands Habitat Conservation Zone to pot fishing for Pacific cod. No pot fishing for Pacific cod occurred within the Pribilof Islands Habitat Conservation Zone in 2015/16.

A. Summary of Major Changes:

1. Management

In 2002, NMFS notified the NPFMC that the PIBKC stock was overfished. A rebuilding plan was implemented in 2003 that included the closure of the stock to directed fishing until the stock was rebuilt. In 2009, NMFS determined that the PIBKC stock was not rebuilding in a timely manner and would not meet the rebuilding horizon of 2014. Subsequently, Amendment 43 to the Crab FMP and Amendment 103 to the BSAI Groundfish FMP to rebuild the PIBKC stock were adopted by the Council in 2012 and approved by the Secretary of Commerce in early 2015. Amendment 103 closed the Pribilof Islands Habitat Conservation Zone to pot fishing for Pacific cod to promote bycatch reduction on PIBKC. Amendment 43 amended the prior rebuilding plan to incorporate new information on the likely rebuilding timeframe for the stock, taking into account environmental conditions and the status and population biology of the stock. No pot fishing for Pacific cod has occurred within the Pribilof Islands Habitat Conservation Zone since 2015/16.

2. Input data

Retained and discard catch time series were updated with 2015/2016 data from the crab and groundfish fisheries. Abundance and biomass for PIBKC in the annual summer NMFS EBS bottom trawl survey were updated for the 2016 survey.

3. Assessment methodology

There are no changes from the 2016/17 assessment. The Tier 4 approach used in this assessment for status determination, based on smoothing the raw survey biomass time series using a random effects model, is identical to that adopted by the CPT and SSC in 2015 and used in the 2015 and 2016 assessments (Stockhausen, 2015, 2016).

4. Assessment results

Total catch mortality in 2016/17 was 0.38 t, which exceeded the OFL (1.16 t). Consequently, overfishing did not occur in 2016/17. The projected MMB-at-mating for 2017/18 decreased slightly from that in 2016/17 but remained below the MSST. Consequently, the stock remains overfished and a directed fishery is prohibited in 2017/18. The OFL, based on average catch, and ABC are identical to last year's values.

B. Responses to SSC and CPT Comments

CPT comments September 2015:

Specific remarks pertinent to this assessment

Use results from the random effects smoothing model to calculate both B_{MSY} and current B for status determination.

Responses to CPT Comments:

Results from the random effects model were used to calculateboth B_{MSY} and current B for status determination.

SSC comments October 2015:

Specific remarks pertinent to this assessment

none

CPT comments May 2016:

Specific remarks pertinent to this assessment

none

SSC comments June 2016:

Specific remarks pertinent to this assessment

none

CPT comments September 2016:

Specific remarks pertinent to this assessment

Apply the same handling mortality to bycatch of PIBKC by fixed gear as is applied to other king crab stocks (0.2).

Responses to CPT Comments:

This assessment uses 0.2 as the handling mortality applied to all fixed gear bycatch.

SSC comments October 2016:

Specific remarks pertinent to this assessment

none

CPT comments May 2017:

Specific remarks pertinent to this assessment

none

SSC comments June 2017:

Specific remarks pertinent to this assessment

none

C. Introduction

1. Stock

Pribilof Islands blue king crab (PIBKC), *Paralithodes platypus.*

2. Distribution

Blue king crab are anomurans in the family Lithodidae, which also includes the red king crab (*Paralithodes camtschaticus*) and golden or brown king crab (*Lithodes aequispinus*) in Alaska. Blue king crabs are found in widely-separated populations across the North Pacific (Figure 1). In the western Pacific, blue king crabs occur off Hokkaido in Japan and isolated populations have been observed in the Sea of Okhotsk and along the Siberian coast to the Bering Straits. In North America, they are found in the Diomede Islands, Point Hope, outer Kotzebue Sound, King Island, and the outer parts of Norton Sound. In the remainder of the Bering Sea, they are found in the waters off St. Matthew Island and the Pribilof Islands. In more southerly areas, blue king crabs are found in the Gulf of Alaska in widely-separated populations that are frequently associated with fjord-like bays (Figure 1). The insular distribution of blue king crab relative to the similar but more broadly distributed red king crab is likely the result of post-glacial-period increases in water temperature that have limited the distribution of this cold-water adapted species (Somerton 1985). Factors that may be directly responsible for limiting the distribution include the physiological requirements for reproduction, competition with the more warm-water adapted red king crab, exclusion by warm-water predators, or habitat requirements for settlement of larvae (Armstrong et al 1985, 1987; Somerton, 1985).

3. Stock structure

Stock structure of blue king crab in the North Pacific is largely unknown. Samples were collected in 2009-2011 by a graduate student at the University of Alaska to support a genetic study on blue king crab population structure. Aspects of blue king crab harvest and abundance trends, phenotypic characteristics, behavior, movement, and genetics will be evaluated by the author following the guidelines in the AFSC report entitled "Guidelines for determination of spatial management units for exploited populations in Alaskan groundfish fishery management plans" by P. Spencer (unpublished report).

The potential for species interactions between blue king crab and red king crab as a potential reason for PIBKC shifts in abundance and distribution were addressed in a previous assessment (Foy, 2013). Foy (2013) compared the spatial extent of both speices in the Pribilof Islands from 1975 to 2009 and found that, in the early 1980's when red king crab first became abundant, blue king crab males and females dominated the 1 to 7 stations where the species co-occurred in the Pribilof Islands District. Spatially, the stations with co-occurance were all dominated by blue king crab and broadly distributed around the Pribilof Islands. In the 1990's, the red king crab population biomass increased substantially as the blue king crab population biomass decreased. During this time period, the number of stations with co-occurance remained around a maximum of 8, but they were equally dominated by both blue king crab and red king crab—sugggesting a direct overlap in distribution at the scale of a survey station. During this time period, the stations dominated by red king crab were dispersed around the Pribilof Islands. Between 2001 and 2009 the blue king crab population decreased dramatically while the red king crab fluctuated. The number of stations dominated by blue king crab in 2001-2009 was similar to that for stations dominated by red king crab for both males and females, suggesting continued competition for similar habitat. The only stations dominated by blue king crab in the latter period are to the north and east of St. Paul Island. Although blue king crab protection measures also afford protection for the red king crab in this region, red king crab stocks continue to fluctuate (more so than simply accounted for by the uncertainty in the survey).

During the years when the fishery was active (1973-1989, 1995-1999), the Pribilof Islands blue king crab (PIBKC) were managed under the Bering Sea king crab Registration Area Q Pribilof District. The southern boundary of this district is formed by a line from 54 36' N lat., 168 W long., to 54 36' N lat., 171 W long., to 55 30' N lat., 171 W. long., to 55 30' N lat., 173 30' E long., while its northern boundary is a line at the latitude of Cape Newenham (58 39' N lat.), its eastern boundary is a line from 54 36' N lat., 168 W long., to 58 39' N lat., 168 W long., to Cape Newenham (58 39' N lat.), and its western boundary is the United States-Russia Maritime Boundary Line of 1991 (ADF&G 2008) (Figure 2). In the Pribilof District, blue king crab occupy the waters adjacent to and northeast of the Pribilof Islands (Armstrong et al. 1987). For assessment purposes, the Pribilof District as defined in Figure 2, with the addition of a 20 nm mile strip to the east of the District (bounded by the dotted red line in Figure 2), is considered to define the stock boundary for PIBKC.

4. Life History

Blue king crab are similar in size and appearance, except for color, to the more widespread red king crab, but are typically biennial spawners with lesser fecundity and somewhat larger sized (ca. 1.2 mm) eggs (Somerton and Macintosh 1983; 1985; Jensen et al. 1985; Jensen and Armstrong 1989; Selin and Fedotov 1996). Blue king crab fecundity increases with size, from approximately 100,000 embryos for a 100-110 mm CL female to approximately 200,000 for a female >140-mm CL (Somerton and MacIntosh 1985). Blue king crab have a biennial ovarian cycle with embryos developing over a 12 or 13-month period depending on whether or not the female is primiparous or multiparous, respectively (Stevens 2006a). Armstrong et al. (1985, 1987), however, estimated the embryonic period for Pribilof blue king crab at 11-12 months, regardless of previous reproductive history. Somerton and MacIntosh (1985) placed development at 14-15 months. It may not be possible for large female blue king crabs to support the energy requirements for annual ovary development, growth, and egg extrusion due to limitations imposed by their habitat, such as poor quality or low abundance of food or reduced feeding activity due to cold water (Armstrong et al. 1987; Jensen and Armstrong 1989). Both the large size reached by Pribilof Islands blue king crab and the generally high productivity of the Pribilof area, however, argue against such environmental constraints. Development of the fertilized embryos occurs in the egg cases attached to the pleopods beneath the abdomen of the female crab and hatching occurs February through April (Stevens 2006b). After larvae are released, large female Pribilof blue king crab will molt, mate, and extrude their clutches the following year in late March through mid April (Armstrong et al. 1987).

Female crabs require an average of 29 days to release larvae, and release an average of 110,033 larvae (Stevens 2006b). Larvae are pelagic and pass through four zoeal larval stages which last about 10 days each, with length of time being dependent on temperature: the colder the temperature the slower the development and vice versa (Stevens et al. 2008). Stage I zoeae must find food within 60 hours as starvation reduces their ability to capture prey (Paul and Paul 1980) and successfully molt. Zoeae consume phytoplankton, the diatom Thalassiosira spp. in particular, and zooplankton. The fifth larval stage is the non-feeding (Stevens et al. 2008) and transitional glaucothoe stage in which the larvae take on the shape of a small crab but retain the ability to swim by using their extended abdomen as a tail. This is the stage at which the larvae searches for appropriate settling substrate and, upon finding it, molts to the first juvenile stage and henceforth remains benthic. The larval stage is estimated to last for 2.5 to 4 months and larvae metamorphose and settle during July through early September (Armstrong et al. 1987; Stevens et al. 2008).

Blue king crab molt frequently as juveniles, growing a few mm in size with each molt. Unlike red king crab juveniles, blue king crab juveniles are not known to form pods. Female king crabs typically reach sexual maturity at approximately five years of age while males may reach maturity at six years of age (NPFMC 2003). Female size at 50% maturity for Pribilof blue king crab is estimated to be 96-mm carapace length (CL) and size at maturity for males, estimated from chela height relative to CL, is estimated to be 108-mm CL (Somerton and MacIntosh 1983). Skip molting occurs with increasing probability for those males larger than 100 mm CL (NMFS 2005).

Longevity is unknown for this species due to the absence of hard parts retained through molts with which to age crabs. Estimates of 20 to 30 years in age have been suggested (Blau 1997). Natural mortality for male Pribilof blue king crabs has been estimated at 0.34-0.94 with a mean of 0.79 (Otto and Cummiskey 1990) and a range of 0.16 to 0.35 for Pribilof and St. Matthew Island stocks combined (Zheng et al. 1997). An annual natural mortality of 0.2 yr^{-1} for all king crab species was adopted in the federal crab fishery management plan for the BSAI areas (Siddeek et al. 2002). A rate of 0.18 yr^{-1} is currently used for PIBKC.

5. Management history

The blue king crab fishery in the Pribilof District began in 1973 with a reported catch of 590 t by eight vessels (Table 9; Figure 3). Landings increased during the 1970s and peaked at a harvest of 5,000 t in the 1980/81 season (Table 9; Figure 3), with an associated increase in effort to 110 vessels (ADFG 2008). The fishery occurred September through January, but usually lasted less than 6 weeks (Otto and Cummiskey 1990; ADFG 2008). The fishery was male only, and legal size was >16.5 cm carapace width (NPFMC 1994). Guideline harvest levels (GHL) were 10 percent of the abundance of mature males or 20 percent of the number of legal males (ADFG 2006).

PIBKC have occurred as bycatch in the eastern Bering Sea snow crab (*Chionoecetes opilio*) fishery, the western Bering Sea Tanner crab (*Chionoecetes bairdi*) fishery, the Bering Sea hair crab (*Erimacrus isenbeckii*) fishery, and the Pribilof red and blue king crab fisheries (Tables 10 and 11). In addition, blue king crab have been taken as bycatch in groundfish fisheries by both fixed and trawl gear, primarily those targeting Pacific cod, flathead sole and yellowfin sole (Tables 10-12).

Amendment 21a to the BSAI Groundfish FMP prohibits the use of trawl gear in the Pribilof Islands Habitat Conservation Area (subsequently renamed the Pribilof Islands Habitat Conservation Zone in Amendment 43; Figure 4), which the amendment also established (NPFMC 1994). The amendment went into effect January 20, 1995 and protects the majority of crab habitat in the Pribilof Islands area from the impact from trawl gear.

Declines in the PIBKC stock after 1995 resulted in a closure of directed fishing from 1999 to the present. The stock was declared overfished in September 2002, and ADFG developed a rebuilding harvest strategy as part of the NPFMC comprehensive rebuilding plan for the stock. The rebuilding plan also included the closure of the stock to directed fishing until it was rebuilt. In 2009, NMFS determined that the PIBKC stock was not rebuilding in a timely manner and would not meet the rebuilding horizon of 2014. Subsequently, Amendment 43 to the King and Tanner Crab Fishery Management Plan (FMP) and Amendment 103 to the BSAI Groundfish FMP to rebuild the PIBKC stock were adopted by the Council in 2012 and approved by the Secretary of Commerce in early 2015. Amendment 103 closes the Pribilof Islands Habitat Conservation Zone (Figure 4) to pot fishing for Pacific cod to promote bycatch reduction on PIBKC. Amendment 43 amends the prior rebuilding plan to incorporate new information on the likely rebuilding timeframe for the stock, taking into account environmental conditions and the status and population biology of the stock (NPFMC 2014a).

D. Data

1. Summary of new information

The time series of retained and discarded catch in the crab fisheries was updated for 2016/17 from ADFG data (no retained catch, no bycatch mortality; Tables 10 and 11). The time series of discards in the groundfish pot and trawl fisheries (Tables 10 and 11) were updated for 2009/10 -2016/17 using NMFS Alaska Regional Office (AKRO) estimates obtained from the AKFIN database (as updated on Aug. 30, 2017). Results from the 2017 NMFS EBS bottom trawl survey were added to the assessment (Tables 15 and 16), based on the "new" standardization described in the 2015 assessment (Stockhausen, 2015).

2. Fishery data

2.a. Retained catch

Retained pot fishery catches (live and deadloss landings data) are provided for 1973/74 to 2015/16 (Table 9, Figure 3), including the 1973/74 to 1987/88 and 1995/96 to 1998/99 seasons when blue king crab were targeted in the Pribilof Islands District. In the 1995/96 to 1998/99 seasons, blue king crab and red king crab were fished under the same Guideline Harvest Level (GHL). Total allowable catch (TAC) for a directed fishery has been set at zero since 1999/2000; there was no retained catch in the 2016/17 crab fishing season.

2.b. Bycatch and discards:

Crab pot fisheries

Non-retained (directed and non-directed) pot fishery catches are provided for sublegal males ($<$ 138 mm CL), legal males ($\geq$ 138 mm CL), and females based on data collected by onboard observers in the crab fisheries (Table 10). Catch weight was calculated by first determining the mean weight (in grams) for crabs in each of three categories: legal non-retained, sublegal, and female. The average weight for each category was then calculated from length frequency tables, where the carapace length (z; in mm) was converted to weight (w; in g) using the following equation:

$$w = \alpha \cdot z^{\beta} \quad (1)$$

Values for the length-to-weight conversion parameters α and β were applied across the time period: males) α=0.000508, β=3.106409; females) α=0.02065, β=2.27 (Daly et al. 2014). Average weights ($\overline{W}$) for each category were calculated using the following equation:

$$\overline{W} = \frac{\sum w_z \cdot n_z}{\sum n_z} \quad (2)$$

where w_z is crab weight-at-size z (i.e., carapace length) using Equation 1, and n_z is the number of crabs observed at that size in the category. Finally, estimated total non-retained weights for each crab fishery were the product of average weight ($\overline{W}$), CPUE based on observer data, and total effort (pot lifts) in each fishery.

Historical non-retained catch data are available from 1996/97 to present from the snow crab general, snow crab CDQ, and Tanner crab fisheries (Table 10, Bowers et al. 2011), although data may be incomplete for some of these fisheries. Prior to 1998/99, limited observer data exists (for catcher-processor vessels only), so non-retained catch before this date is not included here. For this assessment, a 20% handling mortality rate was applied to the bycatch estimates to calculate non-retained crab mortality in these pot fisheries (Table 11). In previous assessments, a handling mortality rate of 50% was applied to bycatch in the pot fisheries. The revised value used here is now consistent with the rates used in other king crab assessments (e.g., Zheng et al., 2016).

No bycatch mortality occurred in the crab fisheries in 2016/17. In 2015/16, though, several PIBKC were incidentally caught in the crab fisheries, yielding an expanded estimate of 0.067 t bycatch mortality (using a handling mortality rate of 20%; Table 10). Bycatch mortality during 2015/16 was the first non-zero bycatch mortality in the crab fisheries since 2010/11.

Groundfish fisheries

The AKRO estimates of non-retained catch from all groundfish fisheries in 2016/17, as available through the AKFIN database (accessed Aug. 30, 2017), are included in this report (Tables 10-12). Updated estimates for 2009/10-2016/17 were obtained through the AKFIN database.

Groundfish bycatch data from before 1999 are available only in INPFC reports and are not included in this assessment. Non-retained crab catch data in the groundfish fisheries are available from 1991/92 to present. Between 1991 and December 2001, bycatch was estimated using the "blend method." From January 2003 to December 2007, bycatch was estimated using the Catch Accounting System (CAS), based on substantially different methods than the "blend." Starting in January 2008, the groundfish observer program changed the method in which they speciate crab to better reflect their hierarchal sampling method and to account for broken crab that in the past were only identified to genus. In addition, the haul-level weights collected by observers were used to estimate the crab weights through CAS instead of applying an annual (global) weight factor to convert numbers to biomass. Spatial resolution was at the NMFS statistical area. Beginning in January 2009, ADFG statistical areas (1^o$ longitude x 0.5^o latitude) were included in groundfish production reports and allowed an increase in the spatial resolution of bycatch estimates from the NMFS statistical areas to the state statistical areas. Bycatch estimates (2009-present) based on the state statistical areas were first provided in the 2013 assessment, and improved methods for aggregating observer data were used in the 2014 and 2015 assessments (see Stockhausen, 2015). The estimates obtained this year are based on the same methods as those used in the 2014-2016 assessments. Detailed results from this process are presented in Appendix A.

To assess crab mortalities in the groundfish fisheries, an 80% handling mortality rate was applied to estimates of bycatch in trawl fisheries, and a 20% handling mortality rate was applied to fixed gear fisheries using pot and hook and line gear (Tables 10-11). As noted above, previous assessments used a handling mortality rate of 50% for bycatch mortality in the fixed gear fisheries.

In 2016/17, fisheries targeting rock sole (*Lepidopsetta spp.*) accounted for 68% of the bycatch of PIBKC in the groundfish fisheries, with fisheries targeting yellowfin sole (*Limanda aspera*) and Pacific cod (*Gadus microcephalus*) accounting for 16% each. In contrast, fisheries targeting Pacific cod accounted for 48% of the estimated total PIBKC bycatch (by weight) in the groundfish fisheries in 2015/16, with fisheries targeting yellowfin sole accounting for another 43% (Table 12). In 2013/14 and 2014/15, bycatch of PIBKC occurred almost exclusively in the Pacific cod fisheries (99.4% by weight, Table 4). The flathead sole (*Hippoglossoides elasodon*) fishery has also accounted for a substantial fraction of the bycatch at times.

Since the 2009/10 crab fishing season, Pribilof Islands blue king crab have been taken as bycatch in the groundfish fisheries only by hook and line and non-pelagic trawl gear (Table 13). Starting in 2015, as a consequence of Amendment 43 to the BSAI Groundfish FMP, the Pribilof Islands Habitat Conservation Area was formally closed to pot fishing for Pacific cod in order to promote recovery of the PIBKC stock. In 2016/17, non-pelagic trawl gear accounted for 83% (by weight) of PIBKC bycatch in the groundfish fisheries. In 2015/16, by contrast, non-pelagic trawl gear accounted for only 52% the bycatch. In 2013/14 and 2014/15, hook and line gear accounted for the total bycatch of PIBKC, while in 2012/13, it accounted for only 20% of the bycatch (by weight)–whereas non-pelagic trawl gear accounted for 80%. Although these appear to be large interannual changes, the actual bycatch amounts involved are fairly small and interannual variability is consequently expected to be rather high.

2.c. Catch-at-length

Not applicable.

3. Survey data

The 2017 NMFS EBS bottom trawl survey was conducted between May and August of this year. Survey results for PIBKC are based on the stock area first defined in the 2013 assessment (Foy, 2013), which includes the Pribilof District and a 20 nm strip adjacent to the eastern edge of the District (Figure 2). The adjacent area was defined as a result of the new rebuilding plan and the concern that crab outside the Pribilof District were not being accounted for in the assessment.

In 2017, the survey caught 23 blue king crab in 86 stations across the stock area, while 20, 28, and 33 crab were caught across the same stations in the 2014-2016 surveys, respectively (Table **??**). Four immature males were caught in 2017, similar to numbers caught in 2014-2016 (5, 4 and 5, respectively). Four mature males (three of which was legal size) were caught in 2017, compared with 5, 13 and 3 in 2014-2016, respectively. Seven immature females were caught in 2017; only one was caught in 2014 and none in 2015, but five in 2016. Finally, eight mature females were caught in 2017, compared with only 4 in 2014, 11 in 2015, and 19 in 2016.

The area-swept estimate of mature male abundance in the stock area at the time of the survey was 91,000 (±89,000), representing an increase from 56,000 (±62,000) in 2016 (Table 15). The abundance estimate for immature males in 2017 was 68,000 (±103,000), while it was 94,000 (±95,000) in 2016. The area-swept estimate for immature female abundance in 2017 was 188,000 (±275,000), larger than in 2016 (132,000 ± 130,000), while that for mature females was only 162,000 (± 169,000), smaller than that in 2016 (323,000 ±328,000). None of the changes were statistically significant.

The area-swept estimate of mature male biomass in the stock area at the time of the 2017 survey was 253 t (±254 t), while it was 129 t (±154 t) in 2016 (Table 16). The biomass estimate for immature males in 2017 was 45 t (±68 t) , compared with 70 t (±67 t) in 2016. The area-swept estimate for immature female biomass in 2017 was 107 t (±170 t); in 2016, it was 49 t (±48 t). For mature females, the estimated swept-area biomass was 152 t (±166 t); in 2016, it was 352 t (±340 t).

One feature that characterizes survey-based estimates of abundance and biomass for PIBKC is the large uncertainty (cv's on the order of 0.5-1) associated with the estimates, which complicates the interpretation of sometimes large interannual swings in estimates (Tables 15 and 16, Figures 5-8). Estimated total abundance of male PIBKC from the NMFS EBS bottom trawl survey declined from ~24 million crab in 1975, the first year of the "standardized" survey, to ~150,000 in 2016 (the lowest estimated abundance since 2004, which was the minimum for the time series; Table 15, Figures 5 and 6). Following a general decline to a low-point in 1985 (~500,000 males), abundance increased by a factor of 10 in the early1990s, then generally declined (with small amplitude oscillations superimposed) to the present. Estimated female abundance generally followed a similar trend. It spiked at 180 million crab in 1980, from ~13 million crab in 1975 and only ~1 million in 1979, then returned to more typical levels in 1981 (~6 million crab). More recently, abundance has fluctuated around 200,000 females. Estimated biomass for both males and females have followed similar trends similar to those in abundance (Table 16, Figures 7 and 8).

Size frequencies for males by shell condition from recent surveys (2012-2017) are illustrated in Figure 9. Size frequencies for all males across the time series are shown in Figure 10. While Figure 10 suggested a recent trend toward larger sizes in 2014-15, this does not appear to have continued in 2016. These plots provide little evidence of recent recruitment.

Size frequencies for females by shell condition are presented in Figure 11 from recent surveys (2012-2017). Size frequencies for all females are shown in 12. These also provide little indication of recent recruitment.

The small numbers of crab caught in recent surveys make it difficult to draw firm conclusions regarding spatial patterns (see figures in Appendix B). That said, the spatial pattern of PIBKC abundance in recent surveys is generally centered fairly compactly within the Pribilof District to the east of St. Paul Island (although 2015 is an exception) and north of St. George Island, within a 60 nm radius of St. Paul.

E. Analytic Approach

1. History of modeling approaches

A catch survey analysis has been used for assessing the stock in the past, although it is not currently in use. In October 2013, the SSC concurred with the CPT that the PIBKC stock falls under Tier 4 for status determination but it recommended that the OFL be calculated using a Tier 5 approach, with ABC based on a 10% buffer. Subsequently, a 25% buffer has been used to calculate ABC.

In the 2013 and 2014 assessments (Foy 2013; Stockhausen 2014), "current" MMB-at-mating was projected from the time of the latest survey using an inverse-variance averaging approach to smoothing annual survey biomass estimates because the uncertainties associated with the annual estimates are extremely large. In the 2015 assessment (Stockhausen, 2015), an alternative approach to smoothing based on a Random Effects model was presented and subsequently adopted by the CPT and SSC to use in estimating B_{MSY} and "current" MMB-at-mating. The Random Effects model (Appendix C) is used in this assessment.

2. Model Description

See Appendix C.

3. Model Selection and Evaluation

Not applicable

4. Results

See Appendix C.

F. Calculation of the OFL

1. Tier Level:

Based on available data, the author recommended classification for this stock is Tier 4 for stock status level determination defined by Amendment 24 to the Fishery Management Plan for the Bering Sea/Aleutian Islands King and Tanner Crabs (NPFMC 2008a).

In Tier 4, stock status is based on the ratio of "current" spawning stock biomass (B) to B_{MSY} (or a proxy thereof, $B_{MSY_{proxy}}$, also referred to as B_{REF}). MSY (maximum sustained yield) is the largest long-term average catch or yield that can be taken from a stock or stock complex under prevailing ecological and environmental conditions. The fishing mortality that, if applied over the long-term, would result in MSY is F_{MSY}. B_{MSY} is the long-term average stock size when fished at FMSY, and is based on mature male biomass at the time of mating (MMB_{mating}), which serves as an approximation for egg production. MMB_{mating} is used as a basis for B_{MSY} because of the complicated female crab life history, unknown sex ratios, and male only fishery. Although B_{MSY} cannot be calculated for a Tier 4 stock, a proxy value ($B_{MSY_{proxy}}$ or B_{REF}) is defined as the average biomass over a specified time period that satisfies the conditions under which B_{MSY} would occur (i.e., equilibrium biomass yielding MSY under an applied F_{MSY}).

The time period for establishing $B_{MSY_{proxy}}$ is assumed to be representative of the stock being fished at an average rate near FMSY and fluctuating around B_{MSY}. The SSC has endorsed using the time periods 1980-84 and 1990-97 to calculate $B_{MSY_{proxy}}$ for Pribilof Islands blue king crab to avoid time periods of low abundance possibly caused by high fishing pressure. Alternative time periods (e.g., 1975 to 1979) have also been considered but rejected (Foy 2013). Considerations for choosing the current time periods included:

A. Production potential

1) Between 2006 and 2013 the stock does appear to be below a threshold for responding to increased production based on the lack of response of the adult stock biomass to slight fluctuations in recruitment (male crab 120-134 mm) (Figure 20 in Foy 2013).
2) An estimate of surplus production ($ASP_t = MMB_{t+1}\text{ˇ}MMB_t + totalcatch_t$) suggested that only meaningful surplus existed only in the late 1970s and early 1980s while minor surplus production in the early 1990s may have led to the increases in biomass observed in the late 1990s.
3) Although a climate regime shift where temperature and current structure changes are likely to impact blue king crab larval dispersal and subsequent juvenile crab distribution, no apparent trends in production before or after 1978 were observed (Foy 2013). There are few empirical data to identify trends that may allude to a production shift. However, further analysis is warranted given the paucity of surplus production and recruitment subsequent to 1981 and the spikes in recruits (male crab 120-134 mm) /spawner (MMB) observed in the early 1990s and 2009 (Figure 21 in Foy 2013).

B. Exploitation rates

Exploitation rates fluctuated during the open fishery periods from 1975 to 1987 and 1995 to 1998 (Figure 20 in Foy 2013) while total catch increased until 1980, before the fishery was closed in 1987, and increased again in 1995 before closing again in 1999 (Figre 22 in Foy 2013). The current $F_{MSY_{proxy}} = M$ is 0.18, so time periods with greater exploitation rates should not be considered to represent a period with an average rate of fishery removals.

C. Recruitment

Subsequent to increases in exploitation rates in the late 1980s and 1990s, the quantity ln(recruits/MMB) dropped, suggesting that exploitation rates at the levels of $F_{MSY_{proxy}} = M$ were not sustainable.

Thus, MMB_{mating} is the basis for calculating $B_{MSY_{proxy}}$. The formulas used to calculate MMB_{mating} from MMB at the time of the survey (MMB_{survey}) are documented in Appendix C. For this stock, $B_{MSY_{proxy}}$ was calculated using the random effects model-smoothed estimates for MMB_{survey} from the survey time series in the formula for MMB_{mating}. $B_{MSY_{proxy}}$ is the average of MMB_{mating} for the years 1980/81-1984/85 and 1990/91-1997/98 (Table 17) and was calculated as 4,108 t.

In this assessment, “current B” (B) is the MMB_{mating} projected for 2017/18. Details of this calculation are also provided in Appendix C. For 2017/18, B = 230 t.

Overfishing is defined as any amount of fishing in excess of a maximum allowable rate, F_{OFL}, which would result in a total catch greater than the OFL. For Tier 4 stocks, a minimum stock size threshold

(MSST) is specified as $0.5 \cdot B_{MSY_{proxy}}$. If B drops below the MSST, the stock is considered to be overfished.

2. Parameters and stock sizes

- $B_{MSY_{proxy}}$ (B_{REF}) = 4,108 t • M = 0.18 yr^{-1} • B = 230 t

3. OFL specification

3.a. Stock status level

In the Tier 4 OFL-setting approach, the "total catch OFL" and the "retained catch OFL" are calculated by applying the F_{OFL} to all crab at the time of the fishery (total catch OFL) or to the mean retained catch determined for a specified period of time (retained catch OFL).

The Tier 4 F_{OFL} is derived using the F_{OFL} Control Rule (Figure 13), where the Stock Status Level (level a, b or c; equations 3-5) is based on the relationship of B to $B_{MSY_{proxy}}$.

Stock Status Level F_{OFL}

$$a. \quad B/B_{MSY_{proxy}} > 1.0 \quad F_{OFL} = \gamma \cdot M \tag{3}$$

$$b. \quad \beta < B/B_{MSY_{proxy}} \leq 1.0 \quad F_{OFL} = \gamma \cdot M[(B/B_{MSY_{proxy}} - \alpha)/(1-\alpha)] \tag{4}$$

$$c. \quad B/B_{MSY_{proxy}} \leq \beta \quad F_{directed} = 0, \quad F_{OFL} \leq F_{MSY} \tag{5}$$

When B/$B_{MSY_{proxy}}$ is greater than 1 (Stock Status Level a), $F_{OFL_{proxy}}$ is given by the product of a scalar (γ=1.0, nominally) and M. When $B/B_{MSY_{proxy}}$ is less than 1 and greater than the critical threshold β (=0.25) (Stock Status Level b), the scalar α (= 0.1) determines the slope of the non-constant portion of the control rule for $F_{OFL_{proxy}}$. Directed fishing mortality is set to zero when the ratio $B/B_{MSY_{proxy}}$ drops below β (Stock Status Level c). Values for α and β are based on a sensitivity analysis of the effects on $B/B_{MSY_{proxy}}$ (NPFMC 2008a).

3.b. Basis for MMB-at-mating

The basis for projecting MMB from the survey to the time of mating is discussed in detail in Appendix C.

3.c. Specification of F_{OFL}, OFL and other applicable measures

Table 5: Basis for the OFL (Table 3 repeated). All units in metric tons.

Year	Tier	B_{MSY}	Current MMB_{mating}	B/B_{MSY} (MMB_{mating})	γ	Years to define B_{MSY}	Natural Mortality	P*
2013/14	4c	3,988	278	0.07	1	1980/81-1984/85 &1990/91-1997/98	0.18	10% buffer
2014/15	4c	4,002	218	0.05	1	1980/81-1984/85 &1990/91-1997/98	0.18	25% buffer
2015/16	4c	4,109	361	0.09	1	1980/81-1984/85 &1990/91-1997/98	0.18	25% buffer
2016/17	4c	4,116	233	0.06	1	1980/81-1984/85 &1990/91-1997/98	0.18	25% buffer
2017/18	4c	4,108	230	0.06	1	1980/81-1984/85 &1990/91-1997/98	0.18	25% buffer

Table 6: Basis for the OFL (Table 4 repeated). All units in millions lbs.

Year	Tier	B_{MSY}	Current MMB_{mating}	B/B_{MSY} (MMB_{mating})	γ	Years to define B_{MSY}	Natural Mortality	P*
2013/14	4c	8.79	0.613	0.07	1	1980/81-1984/85 &1990/91-1997/98	0.18	10% buffer
2014/15	4c	8.82	0.481	0.05	1	1980/81-1984/85 &1990/91-1997/98	0.18	10% buffer
2015/16	4c	9.06	0.795	0.09	1	1980/81-1984/85 &1990/91-1997/98	0.18	25% buffer
2016/17	4c	9.07	0.514	0.06	1	1980/81-1984/85 &1990/91-1997/98	0.18	25% buffer
2017/18	4c	9.06	0.507	0.06	1	1980/81-1984/85 &1990/91-1997/98	0.18	25% buffer

4. Specification of the retained catch portion of the total catch OFL

The retained portion of the catch for this stock is zero (0 t).

5. Recommendations:

For 2017/18, $B_{MSY_{proxy}}$ = 4,108 t, derived as the mean MMB_{mating} from 1980/81 to 1984/85 and 1990/91 to 1997/98 using the random effects model-smoothed survey time series. The stock demonstrated highly variable levels of MMB during both of these periods, likely leading to uncertain approximations for B_{MSY}. Crabs were highly concentrated during the EBS bottom trawl surveys and male biomass estimates were characterized by poor precision due to limited numbers of tows with crab catches.

MMB_{mating} for 2017/18 was estimated at 230 t. The $B/B_{MSY_{proxy}}$ ratio corresponding to the biomass reference is 0.06. $B/B_{MSY_{proxy}}$ is $< \beta$, therefore the stock status level is c, $F_{directed} = 0$, and $F_{OFL} \leq F_{MSY}$ (as determined in the Pribilof Islands District blue king crab rebuilding plan). Total catch OFL calculations were explored in 2008 to adequately reflect the conservation needs with this stock and to acknowledge the existing non-directed catch mortality (NPFMC 2008a). The preferred method was a total catch OFL equivalent to the average catch mortalities between 1999/2000 and 2005/06. This period was after the targeted fishery was closed and did not include recent changes to the groundfish fishery that led to increased blue king crab bycatch. The OFL for 2017/18, based on an average catch mortality, is 1.16 t.

G. Calculation of the ABC

To calculate an Annual Catch Limit (ACL) to account for scientific uncertainty in the OFL, an acceptable biological catch (ABC) control rule was developed such that ACL=ABC. For Tier 3 and 4 stocks, the ABC is set below the OFL by a proportion based a predetermined probability that the ABC would exceed the OFL (P*). Currently, P* is set at 0.49 and represents a proportion of the OFL distribution that accounts for within assessment uncertainty (σ_w) in the OFL to establish the maximum permissible ABC (ABC_{max}). Any additional uncertainty to account for uncertainty outside of the assessment methods (σ_b) is considered as a recommended ABC below ABC_{max}. Additional uncertainty is included in the application of the ABC by adding the uncertainty components as $\sigma_{total} = \sqrt{\sigma_w^2 + \sigma_b^2}$. For the PIBKC stock, the CPT has recommended, and the SSC has approved, a constant buffer of 25% to the OFL (NPFMC, 2014b).

1. Specification of the probability distribution of the OFL used in the ABC

The OFL was set based on a Tier 5 calculation of average catch mortalities between 1999/2000 and 2005/06 to adequately reflect the conservation needs with this stock and to acknowledge the existing non-directed catch mortality. As such, the OFL does not have an associated probability distribution.

2. List of variables related to scientific uncertainty considered in the OFL probability distribution

None. The OFL is based on a Tier 5 calculation and does not have an associated probability distribution. However, compared to other BSAI crab stocks, the uncertainty associated with the estimates of stock size and OFL for Pribilof Islands blue king crab is very high due to insufficient data and the small spatial extent of the stock relative to the survey sampling density. The coefficient of variation for the estimate of mature male biomass from the surveys for the most recent year is 0.51, and has ranged between 0.17 and 1.00 since the 1980 peak in biomass.

3. List of additional uncertainties considered for alternative σ_b applications to the ABC

Several sources of uncertainty are not included in the measures of uncertainty reported as part of the stock assessment:

- Survey catchability and natural mortality uncertainties are not estimated but rather are pre-specified.

- FMSY is assumed to be equal to $\gamma \cdot M$ when applying the OFL control rule, where the proportionality constant γ is assumed to be equal to 1 and M is assumed to be known.
- The coefficients of variation for the survey estimates of abundance for this stock are very high.
- B_{MSY} is assumed to be equivalent to average mature male biomass. However, stock biomass has fluctuated greatly and targeted fisheries only occurred from 1973-1987 and 1995-1998 so considerable uncertainty exists with this estimate of B_{MSY}.

4. Recommendations:

For 2017/18, $F_{directed} = 0$ and the total catch OFL is based on catch biomass would maintain the conservation needs with this stock and acknowledge the existing non-directed catch mortality. In this case, the ABC based on a 25% buffer of the average catch between 1999/2000 and 2005/2006 would be 0.87 t.

Table 7: Management performance (Table). All units in metric tons. The OFL is a total catch OFL for each year.

Year	MSST	Biomass (MMB_{mating})	TAC	Retained Catch	Total Catch Mortality	OFL	ABC
2013/14	2,001 A	225 A	closed	0	0.03	1.16	1.04
2014/15	2,055 A	344 A	closed	0	0.07	1.16	0.87
2015/16	2,058 A	361 A	closed	0	1.18	1.16	0.87
2016/17	2,054 A	233 A	closed	0	0.38	1.16	0.87
2017/18	--	230 B	--	--	--	1.16	0.87

Notes:

A – Based on data available to the Crab Plan Team at the time of the assessment following the end of the crab fishing year.

B – Based on data available to the Crab Plan Team at the time of the assessment for the crab fishing year.

Table 8: Management performance (Table 2 repeated). All units in the table are million pounds.

Year	MSST	Biomass (MMB_{mating})	TAC	Retained Catch	Total Catch Mortality	OFL	ABC
2013/14	4.411 A	0.496 A	closed	0	0.0001	0.0026	0.002
2014/15	4.531 A	0.758 A	closed	0	0.0002	0.0026	0.002
2015/16	4.537 A	0.796 A	closed	0	0.0026	0.0026	0.002
2016/17	4.528 A	0.514 A	closed	0	0.0008	0.0026	0.002
2017/18	--	0.507 A	--	--	--	0.0026	0.002

H. Rebuilding Analyses

Rebuilding analyses results summary: A revised rebuilding plan analysis was submitted to the U.S. Secretary of Commerce in 2014 because NMFS determined that the stock was not rebuilding in a timely manner and would not meet the rebuilding horizon of 2014. The Secretary approved the plan in 2015, as well as the two amendments that implement it (Amendment 43 to the King and Tanner Crab Fishery Management Plan and Amendment 103 to the BSAI Groundfish Fishery Management Plan). These amendments impose a closure to all fishing for Pacific cod with pot gear in the Pribilof Islands Habitat Conservation Zone. This measure was designed to protect the main concentration of the stock from the fishery with the highest observed rates of bycatch (NPFMC, 2014a). The area has been closed to trawling since 1995.

I. Data Gaps and Research Priorities

Given the large CVs associated with the survey abundance and biomass estimates for the Pribilof Islands blue king crab stock, assessment of this species might benefit from additional surveys using alternative gear at finer spatial resolution. Jared Weems, a PhD student at University of Alaska, Fairbanks, is conducting research on alternative survey designs, including visual censuses, drop camera, and collector traps to better quantify PIBKC in a study funded by NPRB. Other data gaps include stock-specific natural mortality rates and a lack of understanding regarding processes apparently preventing successful recruitment to the Pribilof District.

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Tables

Table 9: Total retained catches from directed fisheries for Pribilof Islands District blue king crab (Bowers et al. 2011; D. Pengilly and J. Webb, ADFG, personal communications).

Year	Retained Catch		Avg. CPUE
	Abundance	Biomass (t)	legal crabs/pot
1973/1974	174,420	579	26
1974/1975	908,072	3,224	20
1975/1976	314,931	1,104	19
1976/1977	855,505	2,999	12
1977/1978	807,092	2,929	8
1978/1979	797,364	2,901	8
1979/1980	815,557	2,719	10
1980/1981	1,497,101	4,976	9
1981/1982	1,202,499	4,119	7
1982/1983	587,908	1,998	5
1983/1984	276,364	995	3
1984/1985	40,427	139	3
1985/1986	76,945	240	3
1986/1987	36,988	117	2
1987/1988	95,130	318	2
1988/1989	0	0	--
1989/1990	0	0	--
1990/1991	0	0	--
1991/1992	0	0	--
1992/1993	0	0	--
1993/1994	0	0	--
1994/1995	0	0	--
1995/1996	190,951	628	5
1996/1997	127,712	425	4
1997/1998	68,603	232	3
1998/1999	68,419	234	3
1999/2000 - 2016/2017	0	0	--

Table 10: Total bycatch (non-retained catch) from the directed and non-directed fisheries for Pribilof Islands District blue king crab. Crab fishery bycatch data is not available prior to 1996/1997 (Bowers et al. 2011; D. Pengilly ADFG). Gear-specific groundfish fishery data is not available prior to 1991/1992 (J. Mondragon, NMFS).

fishery year	crab (pot) fisheries (t)			groundfish fisheries (t)	
	females	legal males	sublegal males	fixed gear	trawl gear
1991/92	--	--	--	0.067	6.199
1992/93	--	--	--	0.879	60.791
1993/94	--	--	--	0.000	34.232
1994/95	--	--	--	0.035	6.856
1995/96	--	--	--	0.108	1.284
1996/97	0.000	0.000	0.807	0.031	0.067
1997/98	0.000	0.000	0.000	1.462	0.130
1998/99	3.715	2.295	0.467	19.800	0.079
1999/00	1.969	3.493	4.291	0.795	0.020
2000/01	0.000	0.000	0.000	0.116	0.023
2001/02	0.000	0.000	0.000	0.833	0.029
2002/03	0.000	0.000	0.000	0.071	0.297
2003/04	0.000	0.000	0.000	0.345	0.227
2004/05	0.000	0.000	0.000	0.816	0.002
2005/06	0.050	0.000	0.000	0.353	1.339
2006/07	0.104	0.000	0.000	0.138	0.074
2007/08	0.136	0.000	0.000	3.993	0.132
2008/09	0.000	0.000	0.000	0.141	0.473
2009/10	0.000	0.000	0.000	0.216	0.207
2010/11	0.000	0.000	0.186	0.039	0.056
2011/12	0.000	0.000	0.000	0.112	0.007
2012/13	0.000	0.000	0.000	0.167	0.669
2013/14	0.000	0.000	0.000	0.064	0.000
2014/15	0.000	0.000	0.000	0.144	0.000
2015/16	0.103	0.000	0.230	0.744	0.808
2016/17	0.000	0.000	0.000	0.090	0.455

Table 11: Total bycatch (discard) mortality from directed and non-directed fisheries for Pribilof Islands District blue king crab. Gear-specific handling mortalities were applied to estimates of non-retained catch from Table 2 for fixed gear (i.e., pot and hook/line; 0.2) and trawl gear (0.8).

fishery year	crab (pot) fisheries (t)			groundfish fisheries (t)		total bycatch mortality (t)
	females	legal males	sublegal males	fixed gear	trawl gear	
1991/92	--	--	--	0.013	4.959	4.973
1992/93	--	--	--	0.176	48.633	48.809
1993/94	--	--	--	0.000	27.386	27.386
1994/95	--	--	--	0.007	5.485	5.492
1995/96	--	--	--	0.022	1.027	1.049
1996/97	0.000	0.000	0.161	0.006	0.054	0.221
1997/98	0.000	0.000	0.000	0.292	0.104	0.396
1998/99	0.743	0.459	0.093	3.960	0.063	5.319
1999/00	0.394	0.699	0.858	0.159	0.016	2.125
2000/01	0.000	0.000	0.000	0.023	0.018	0.042
2001/02	0.000	0.000	0.000	0.167	0.023	0.190
2002/03	0.000	0.000	0.000	0.014	0.238	0.252
2003/04	0.000	0.000	0.000	0.069	0.182	0.251
2004/05	0.000	0.000	0.000	0.163	0.002	0.165
2005/06	0.010	0.000	0.000	0.071	1.071	1.152
2006/07	0.021	0.000	0.000	0.028	0.059	0.108
2007/08	0.027	0.000	0.000	0.799	0.106	0.931
2008/09	0.000	0.000	0.000	0.028	0.378	0.407
2009/10	0.000	0.000	0.000	0.043	0.165	0.209
2010/11	0.000	0.000	0.037	0.008	0.045	0.090
2011/12	0.000	0.000	0.000	0.022	0.006	0.028
2012/13	0.000	0.000	0.000	0.033	0.535	0.568
2013/14	0.000	0.000	0.000	0.013	0.000	0.013
2014/15	0.000	0.000	0.000	0.029	0.000	0.029
2015/16	0.021	0.000	0.046	0.149	0.646	0.861
2016/17	0.000	0.000	0.000	0.018	0.364	0.382

Table 12: Bycatch (in kg) of PIBKC in the groundfish fisheries, by target type.

Crab Fishery Year	% bycatch (biomass) by trip target				total bycatch (# crabs)
	yellowfin sole %	Pacific cod %	flathead sole %	rock sole %	
2003/04	47	22	31	< 1	252
2004/05	< 1	100	< 1	< 1	259
2005/06	< 1	97	3	< 1	757
2006/07	54	20	< 1	26	96
2007/08	3	96	1	< 1	2,950
2008/09	77	23	< 1	< 1	295
2009/10	31	51	17	< 1	281
2010/11	< 1	39	59	< 1	48
2011/12	< 1	100	< 1	< 1	62
2012/13	77	20	3	< 1	410
2013/14	< 1	99	< 1	< 1	39
2014/15	< 1	99	< 1	< 1	64
2015/16	43	48	9	< 1	609
2016/17	16	16	<1	68	580

Table 13: Bycatch (in kg) of PIBKC in the groundfish fisheries, by gear type.

Crab Fishery Year	% bycatch (biomass) by gear type				total bycatch (# crabs)
	non-pelagic trawl %	pelagic trawl %	hook and line %	pot %	
2003/04	79	0	21	0	252
2004/05	1	0	99	0	259
2005/06	3	0	18	79	757
2006/07	20	0	20	0	96
2007/08	3	0	1	95	2,950
2008/09	77	0	23	0	295
2009/10	49	0	7	44	281
2010/11	59	0	41	0	48
2011/12	6	0	94	0	62
2012/13	80	0	20	0	410
2013/14	0	0	100	0	39
2014/15	0	0	100	0	64
2015/16	52	0	48	0	609
2016/17	83	0	17	0	580

Table 14: Summary of recent NMFS annual EBS bottom trawl surveys for the Pribilof Islands District blue king crab by stock component.

year	Stock Component	Number of tows in District	Tows with crab	Number of crab measured	Abundance (millions)		Biomass (mt)	
					estimate	95% CI	estimate	95% CI
2017	Immature male	86	2	4	0.068	0.103	45	68
	Mature male	86	4	4	0.091	0.089	253	254
	Legal male	86	3	3	0.072	0.083	223	250
	Immature female	86	3	7	0.188	0.275	107	170
	Mature female	86	4	8	0.162	0.169	152	166
2016	Immature male	86	4	5	0.094	0.095	70	67
	Mature male	86	3	3	0.056	0.062	129	154
	Legal male	86	1	1	0.019	0.038	68	133
	Immature female	86	4	5	0.132	0.130	49	48
	Mature female	86	7	19	0.323	0.328	352	340
2015	Immature male	86	2	4	0.076	0.113	82	120
	Mature male	86	8	13	0.234	0.168	622	480
	Legal male	86	5	7	0.125	0.109	428	385
	Immature female	86	0	0	0.000	0.000	0	0
	Mature female	86	4	11	0.202	0.260	160	207
2014	Immature male	86	3	5	0.091	0.105	83	102
	Mature male	86	2	5	0.092	0.128	233	320
	Legal male	86	2	5	0.092	0.128	233	320
	Immature female	86	1	1	0.028	0.054	16	32
	Mature female	86	3	4	0.074	0.088	91	108

Table 15: Abundance time series for Pribilof Islands blue king crab from the NMFS annual EBS bottom trawl survey.

Year	Males								Females	
	immature		mature		legal		total		total	
	abundance	cv	abundance	cv	abundance	cv	abundance	cv	abundance	cv
1975	8,475,781	0.57	15,288,169	0.50	9,051,486	0.50	23,763,950	0.47	13,147,587	0.61
1976	4,959,559	0.95	4,782,105	0.45	4,012,289	0.47	9,741,664	0.59	8,138,538	0.91
1977	4,215,865	0.46	13,043,983	0.74	11,768,927	0.77	17,259,848	0.63	14,731,651	0.86
1978	2,421,458	0.50	6,140,638	0.50	3,922,874	0.62	8,562,096	0.43	5,987,437	0.66
1979	79,355	0.70	4,107,868	0.33	3,017,119	0.31	4,187,222	0.32	1,311,351	0.77
1980	2,732,728	0.47	7,842,342	0.41	6,244,058	0.42	10,575,070	0.40	183,684,143	0.98
1981	2,099,475	0.32	3,834,431	0.18	3,245,951	0.18	5,933,906	0.21	6,260,015	0.42
1982	1,371,283	0.28	2,353,813	0.18	2,071,468	0.19	3,725,096	0.17	8,713,260	0.63
1983	1,030,732	0.36	1,851,301	0.19	1,321,395	0.17	2,882,033	0.22	9,771,695	0.76
1984	517,574	0.40	770,643	0.22	558,226	0.25	1,288,217	0.21	3,234,663	0.37
1985	67,765	0.60	428,076	0.28	270,242	0.29	495,841	0.27	746,266	0.36
1986	18,904	1.00	480,198	0.31	460,311	0.31	499,102	0.30	2,138,616	0.88
1987	621,541	0.83	903,180	0.41	830,151	0.42	1,524,721	0.43	1,072,008	0.48
1988	1,238,053	0.84	237,868	0.51	237,868	0.51	1,475,921	0.71	1,363,093	0.64
1989	3,514,764	0.59	239,948	0.62	239,948	0.62	3,754,712	0.58	3,777,855	0.58
1990	2,449,864	0.60	1,470,419	0.63	571,708	0.54	3,920,283	0.58	4,223,169	0.56
1991	1,920,443	0.37	2,014,086	0.36	1,237,558	0.44	3,934,529	0.34	3,572,899	0.35
1992	2,435,796	0.59	1,935,278	0.42	1,154,465	0.45	4,371,074	0.48	3,946,863	0.52
1993	1,483,524	0.52	1,875,500	0.31	1,114,301	0.30	3,359,024	0.34	2,663,329	0.38
1994	638,520	0.37	1,294,263	0.34	935,269	0.34	1,932,783	0.33	5,191,978	0.44
1995	1,146,803	0.89	3,101,712	0.60	2,186,409	0.62	4,248,514	0.67	4,697,035	0.49
1996	719,430	0.63	1,712,015	0.28	1,269,275	0.26	2,431,445	0.33	5,321,557	0.46
1997	467,234	0.53	1,201,296	0.29	932,852	0.28	1,668,530	0.34	2,934,717	0.39
1998	949,447	0.46	967,098	0.25	797,187	0.25	1,916,545	0.31	2,329,750	0.37
1999	159,536	0.37	617,258	0.33	452,740	0.34	776,794	0.33	2,755,976	0.49
2000	163,835	0.56	725,051	0.30	527,589	0.30	888,885	0.31	1,363,070	0.46
2001	92,918	0.65	522,239	0.71	445,863	0.74	615,157	0.69	1,715,981	0.74
2002	0	0.00	225,476	0.47	207,146	0.49	225,476	0.47	1,240,582	0.78
2003	45,271	0.72	228,897	0.39	213,572	0.40	274,168	0.34	1,187,583	0.72
2004	87,651	0.59	47,905	0.56	15,584	1.00	135,556	0.42	168,094	0.51
2005	1,981,338	0.96	91,932	0.71	91,932	0.71	2,073,270	0.92	2,557,310	0.89
2006	138,118	0.49	55,579	0.56	38,242	0.70	193,697	0.42	542,588	0.62
2007	246,165	0.72	110,080	0.85	54,403	0.75	356,245	0.64	288,245	0.59
2008	233,919	0.93	18,256	1.00	18,256	1.00	252,174	0.86	779,488	0.75
2009	267,717	0.63	248,626	0.73	68,117	0.59	516,343	0.68	629,385	0.76
2010	101,151	0.84	130,465	0.49	64,703	0.48	231,616	0.61	414,660	0.62
2011	0	0.00	165,525	0.79	129,098	0.87	165,525	0.79	54,601	0.56
2012	194,522	1.00	272,233	0.80	164,165	0.68	466,755	0.88	346,777	0.70
2013	76,351	1.00	104,361	0.86	68,726	0.80	180,712	0.64	195,644	0.53
2014	90,990	0.59	91,856	0.71	91,856	0.71	182,846	0.57	102,088	0.51
2015	75,575	0.77	233,630	0.37	124,592	0.45	309,205	0.41	202,464	0.65
2016	94,022	0.52	55,852	0.56	19,345	1.00	149,874	0.49	454,450	0.50
2017	68,238	0.77	90,645	0.50	71,937	0.59	158,884	0.46	349,659	0.54

Table 16: Biomass time series for Pribilof Islands blue king crab from the NMFS annual EBS bottom trawl survey.

Year	Males								Females	
	immature		mature		legal		total		total	
	biomass (t)	cv	biomass (t)	cv	biomass (t)	cv	biomass (t)	cv	biomass (t)	cv
1975	8,341	0.52	38,054	0.50	27,016	0.50	46,395	0.47	12,442	0.64
1976	4,129	0.94	14,059	0.45	12,649	0.47	18,188	0.45	5,792	0.89
1977	3,713	0.44	42,618	0.77	40,366	0.78	46,332	0.73	13,572	0.87
1978	2,765	0.51	17,370	0.56	13,517	0.64	20,135	0.51	6,492	0.72
1979	61	0.79	10,959	0.32	9,040	0.31	11,021	0.31	1,189	0.76
1980	2,084	0.49	23,553	0.43	20,679	0.45	25,637	0.42	212,303	0.98
1981	1,704	0.30	11,628	0.17	10,554	0.17	13,332	0.18	6,484	0.46
1982	1,152	0.23	7,389	0.19	6,893	0.19	8,541	0.17	9,377	0.67
1983	962	0.36	5,409	0.18	4,474	0.17	6,371	0.19	10,248	0.78
1984	130	0.36	2,216	0.23	1,824	0.25	2,345	0.22	3,085	0.38
1985	39	0.73	1,055	0.27	756	0.28	1,094	0.26	525	0.44
1986	4	1.00	1,505	0.30	1,473	0.31	1,508	0.30	2,431	0.90
1987	191	0.78	2,923	0.41	2,781	0.41	3,115	0.40	913	0.53
1988	170	0.71	842	0.53	842	0.53	1,012	0.46	718	0.47
1989	1,275	0.62	828	0.64	828	0.64	2,102	0.55	1,746	0.50
1990	2,004	0.66	3,078	0.60	1,514	0.52	5,082	0.61	2,929	0.49
1991	1,377	0.39	4,690	0.39	3,326	0.45	6,067	0.37	2,776	0.38
1992	1,801	0.51	4,391	0.42	3,035	0.45	6,192	0.43	2,649	0.46
1993	1,089	0.54	4,556	0.31	3,203	0.30	5,644	0.30	2,092	0.40
1994	619	0.39	3,410	0.34	2,806	0.35	4,029	0.34	4,893	0.44
1995	968	0.86	8,360	0.60	6,787	0.62	9,328	0.63	4,279	0.50
1996	745	0.61	4,641	0.27	3,873	0.27	5,386	0.28	5,585	0.49
1997	381	0.55	3,233	0.28	2,765	0.27	3,614	0.29	3,028	0.41
1998	692	0.41	2,798	0.25	2,510	0.25	3,490	0.25	2,182	0.39
1999	161	0.40	1,729	0.34	1,426	0.35	1,890	0.33	2,868	0.47
2000	113	0.68	2,091	0.30	1,746	0.31	2,205	0.30	1,462	0.46
2001	87	0.76	1,599	0.73	1,461	0.76	1,686	0.73	1,817	0.72
2002	0	0.00	680	0.51	647	0.52	680	0.51	1,401	0.78
2003	19	0.98	702	0.40	671	0.41	721	0.39	1,307	0.73
2004	36	0.65	107	0.58	48	1.00	143	0.46	123	0.50
2005	326	0.94	344	0.71	344	0.71	670	0.59	847	0.61
2006	87	0.58	166	0.60	139	0.70	253	0.46	576	0.71
2007	197	0.74	306	0.80	206	0.73	503	0.66	282	0.71
2008	212	0.95	46	1.00	46	1.00	258	0.80	672	0.70
2009	254	0.68	497	0.71	187	0.60	751	0.70	625	0.82
2010	92	0.85	303	0.46	190	0.48	395	0.52	394	0.63
2011	0	0.00	461	0.84	399	0.89	461	0.84	37	0.67
2012	165	1.00	644	0.74	459	0.64	809	0.79	237	0.64
2013	15	1.00	250	0.80	190	0.75	265	0.75	166	0.65
2014	83	0.62	233	0.70	233	0.70	317	0.57	108	0.53
2015	82	0.75	622	0.39	428	0.46	703	0.39	160	0.66
2016	70	0.49	129	0.61	68	1.00	199	0.52	401	0.48
2017	45	0.77	253	0.51	223	0.57	298	0.47	259	0.53

Table 17: Estimates of mature male biomass (MMB) at the time of mating for Pribilof Islands blue king crab using: (1) the "raw" survey biomass time series and (2) the survey biomass time series smoothed using the Random Effects Model. Shaded rows signify averaging time period for B_{MSY}/MSST. The 2017/18 estimates are projected values (see Appendix C).

year	raw			RE-smoothed		
	biomass (t)	lower CI (t)	upper CI (t)	biomass (t)	lower CI (t)	upper CI (t)
1975	38,054	20,760	69,754	26,901	16,826	43,010
1976	14,059	8,104	24,391	19,927	13,389	29,657
1977	42,618	17,814	101,958	21,265	13,591	33,271
1978	17,370	8,912	33,852	16,975	11,333	25,424
1979	10,959	7,386	16,262	13,329	9,743	18,236
1980	23,553	13,894	39,925	15,605	11,032	22,074
1981	11,628	9,321	14,507	11,423	9,355	13,947
1982	7,389	5,825	9,374	7,449	6,052	9,168
1983	5,409	4,316	6,778	5,081	4,155	6,213
1984	2,216	1,659	2,959	2,347	1,841	2,993
1985	1,055	754	1,476	1,350	1,020	1,786
1986	1,505	1,030	2,199	1,555	1,157	2,091
1987	2,923	1,761	4,853	1,928	1,352	2,749
1988	842	446	1,591	1,427	946	2,153
1989	828	392	1,749	1,599	1,027	2,488
1990	3,078	1,513	6,261	2,603	1,718	3,944
1991	4,690	2,910	7,556	3,812	2,677	5,428
1992	4,391	2,612	7,382	4,181	2,940	5,947
1993	4,556	3,100	6,694	4,329	3,200	5,856
1994	3,410	2,220	5,240	4,017	2,907	5,551
1995	8,360	4,091	17,086	4,942	3,336	7,322
1996	4,641	3,309	6,509	4,384	3,316	5,796
1997	3,233	2,284	4,575	3,322	2,523	4,373
1998	2,798	2,043	3,833	2,705	2,085	3,508
1999	1,729	1,136	2,631	1,976	1,451	2,691
2000	2,091	1,443	3,031	1,836	1,358	2,483
2001	1,599	689	3,710	1,265	830	1,927
2002	680	369	1,254	784	528	1,163
2003	702	428	1,150	549	382	788
2004	107	53	214	278	179	432
2005	344	152	780	266	169	419
2006	166	81	339	225	143	354
2007	306	125	753	230	142	374
2008	46	16	134	210	126	351
2009	497	219	1,130	294	186	466
2010	303	173	532	321	214	482
2011	461	180	1,180	372	232	596
2012	644	277	1,496	399	248	642
2013	250	102	615	345	215	555
2014	233	104	524	339	217	529
2015	622	382	1,011	399	275	579
2016	129	62	265	258	167	400
2017	253	136	470	256	158	414

Figures

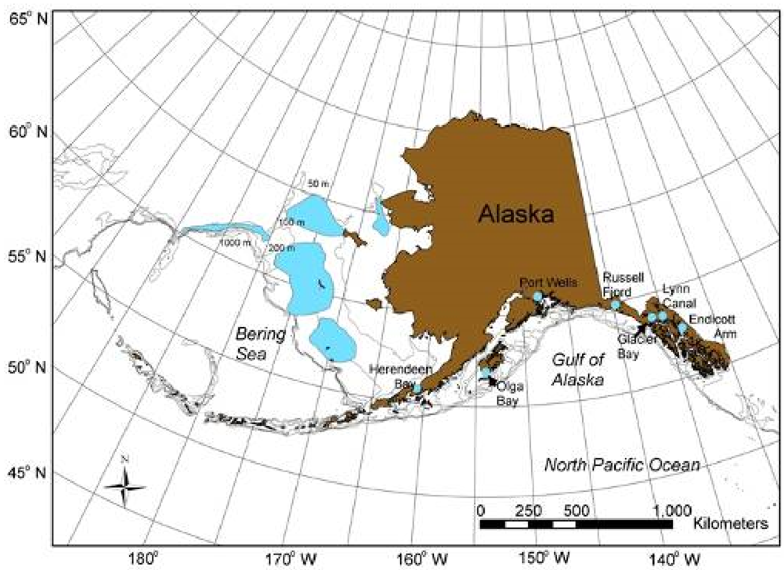

Figure 1: Distribution of blue king crab, *Paralithodes platypus*, in Alaskan waters.

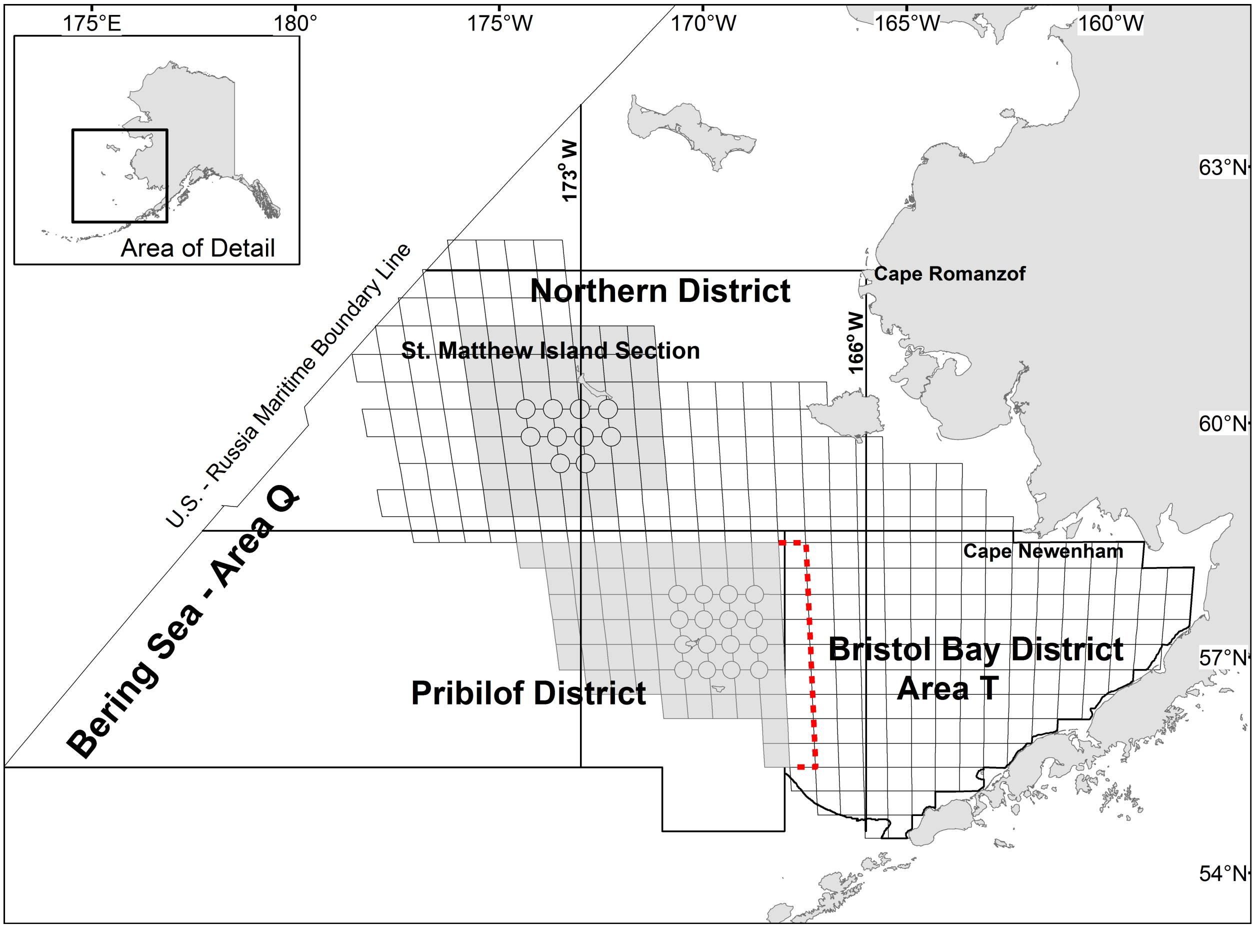

Figure 2: Map of the ADFG King Crab Registration Area Q (Bering Sea), showing (among others) the Pribilof District, which constitutes the stock boundary for PIBKC. The figure also indicates the additional 20nm strip (red dotted line) added in 2013 for calculating biomass and catch data in the Pribilof District.

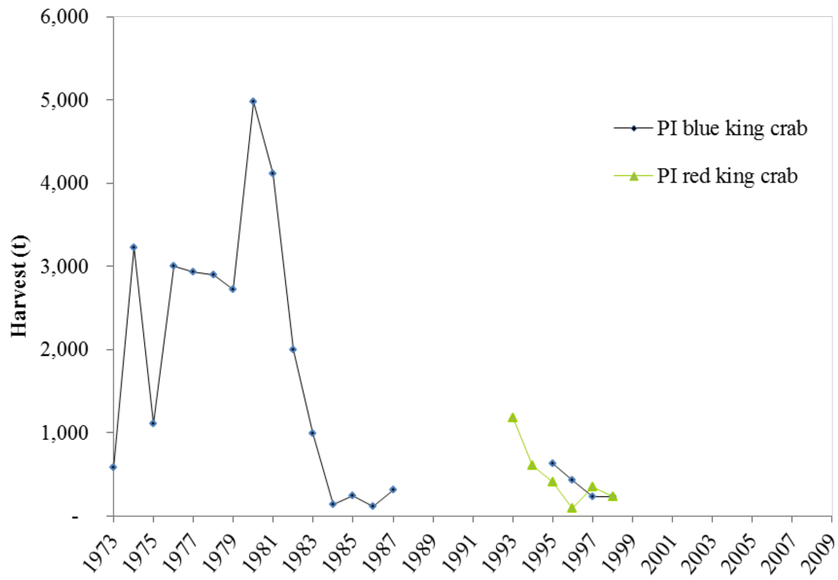

Figure 3: Historical harvests and Guideline Harvest Levels (GHLs) for Pribilof Islands red and blue king crab (from Bowers et al., 2011).

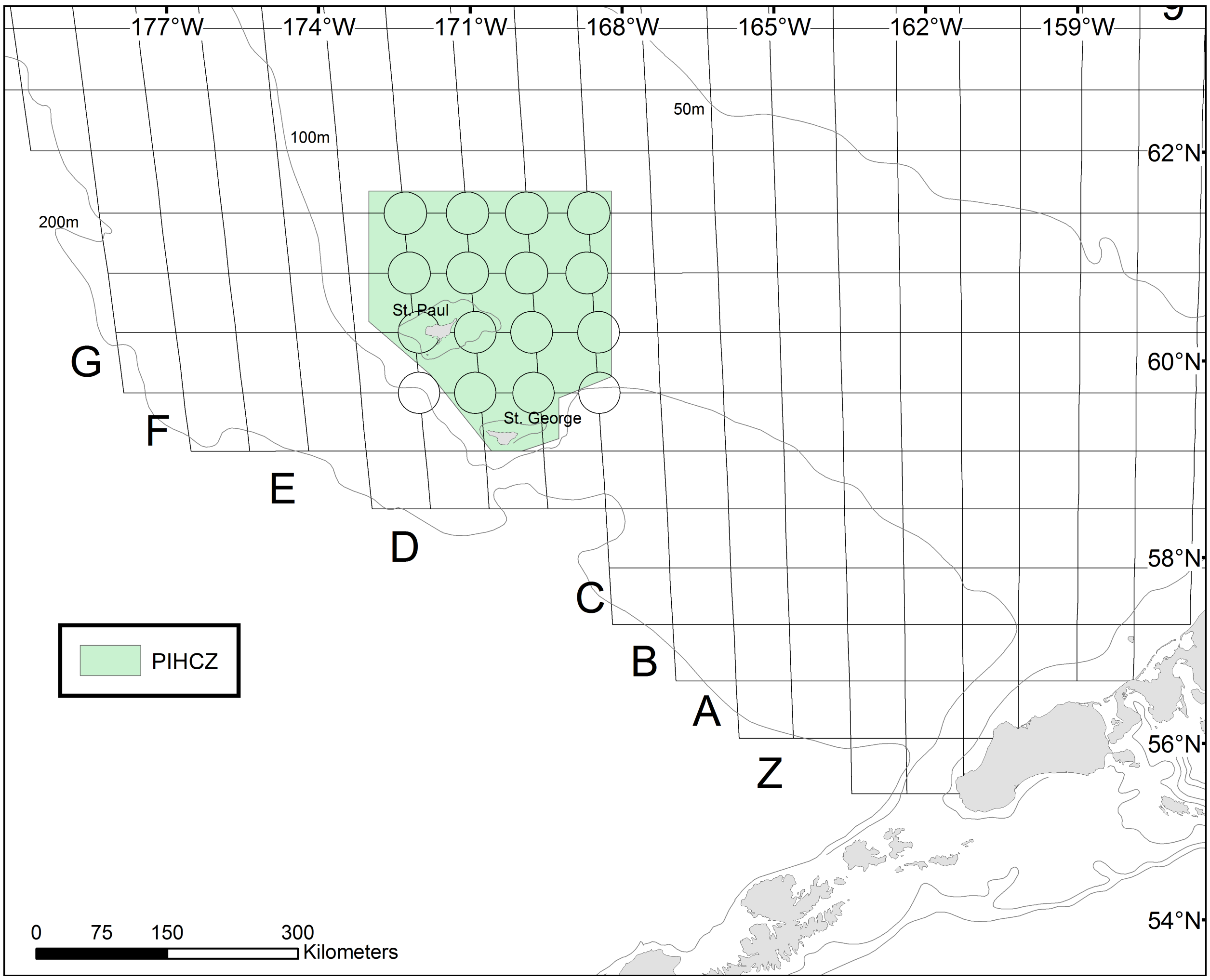

Figure 4: The shaded area shows the Pribilof Islands Habitat Conservation Zone (PIHCZ). Trawl fishing is prohibited year-round in this zone (as of 1995), as is pot fishing for Pacific cod (as of 2015). Also shown is a portion of the NMFS annual EBS bottom trawl survey grid.

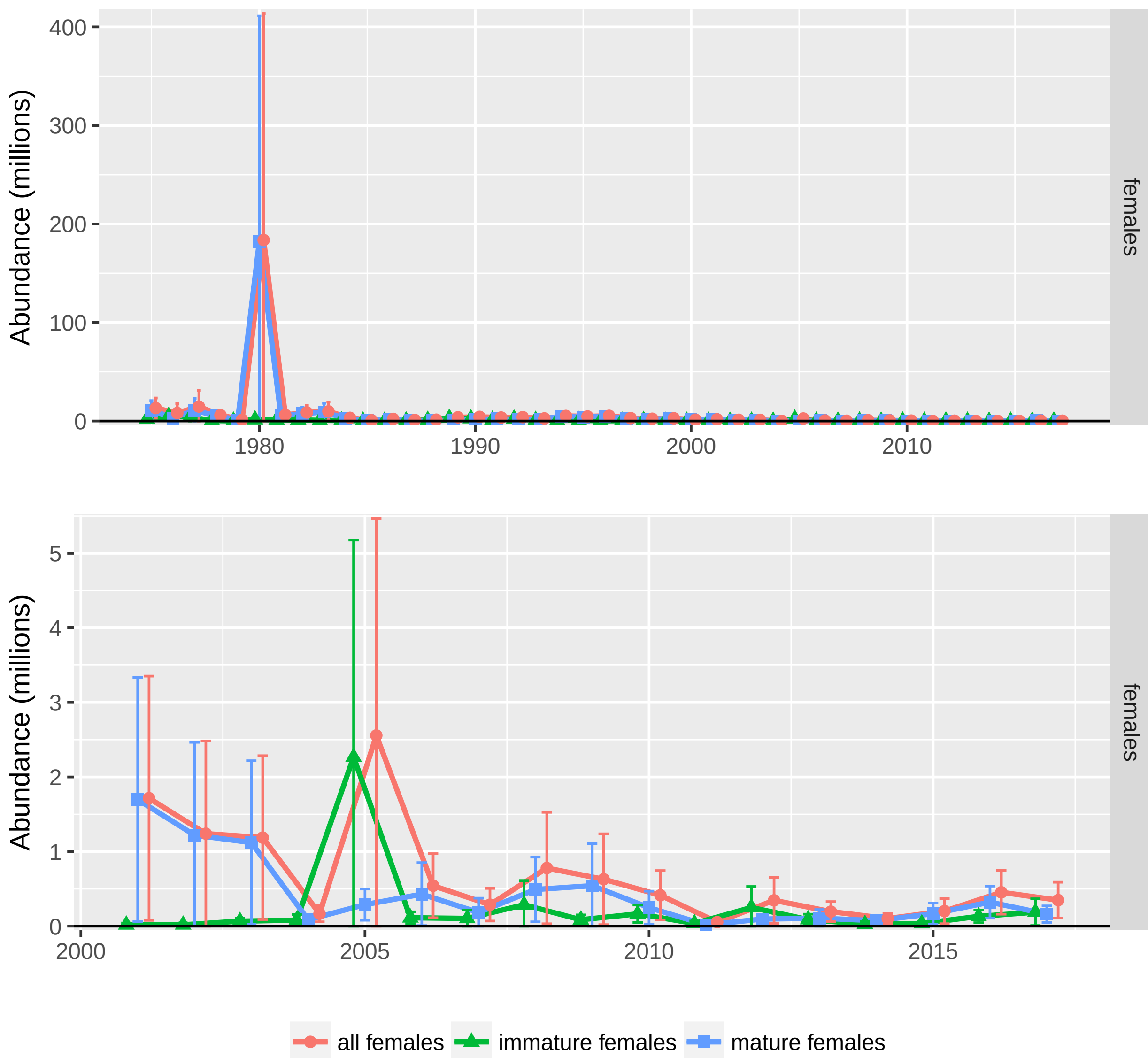

Figure 5: Time series of survey abundance for females (immature, mature, and total).

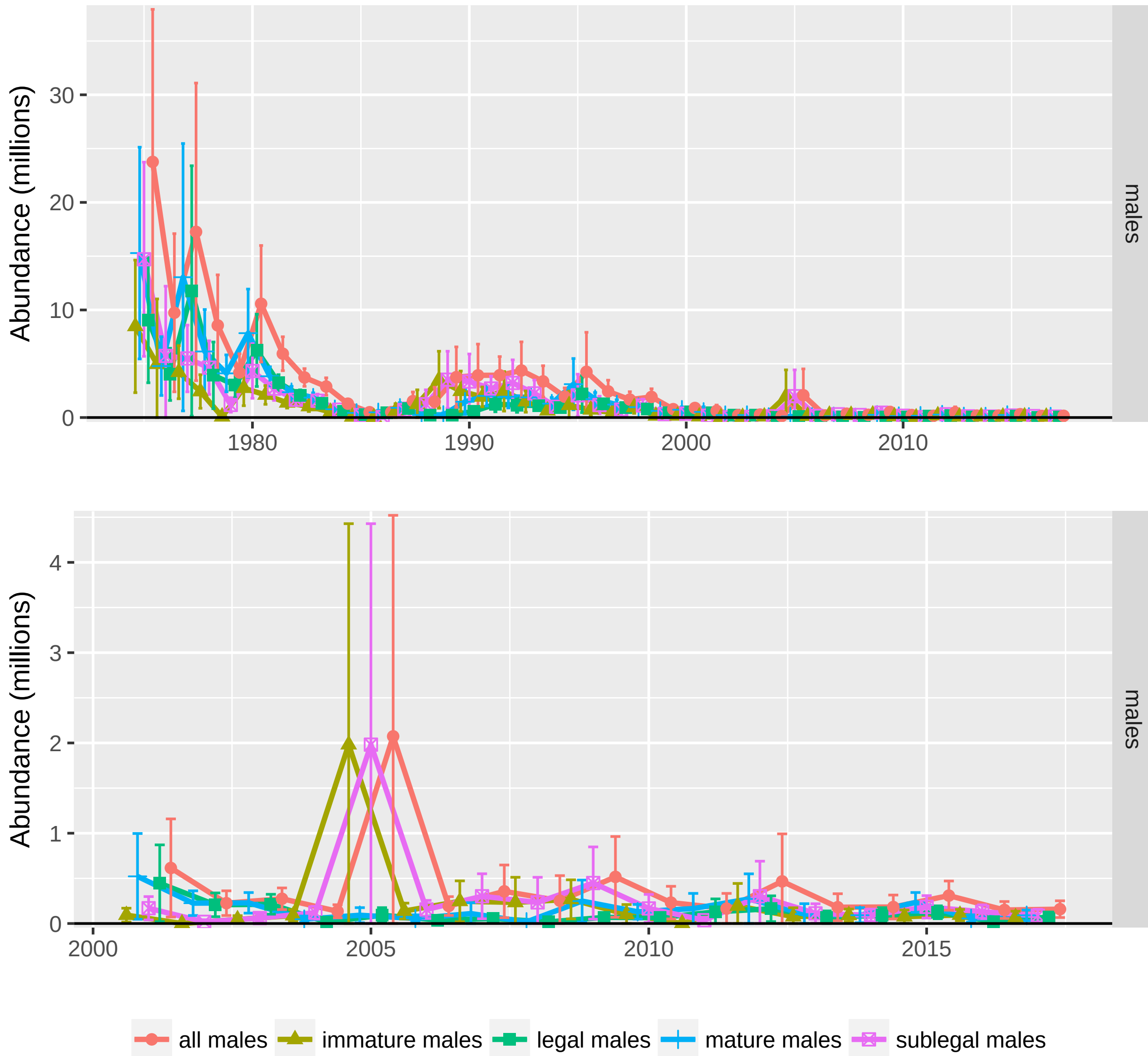

Figure 6: Time series of survey abundance for males in several categories (immature, mature, sublegal, legal and total).

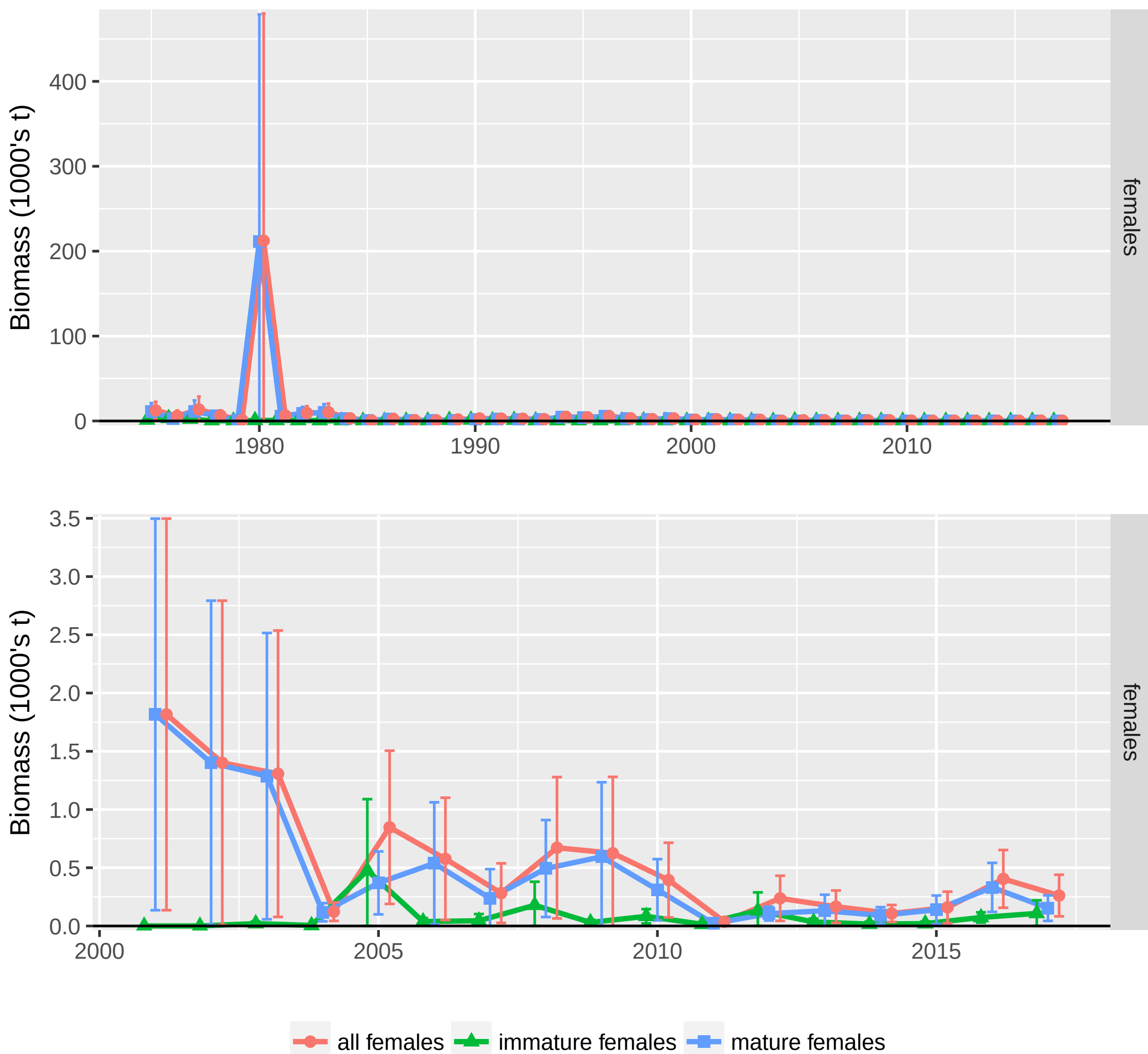

Figure 7: Time series of survey abundance for females (immature, mature, and total).

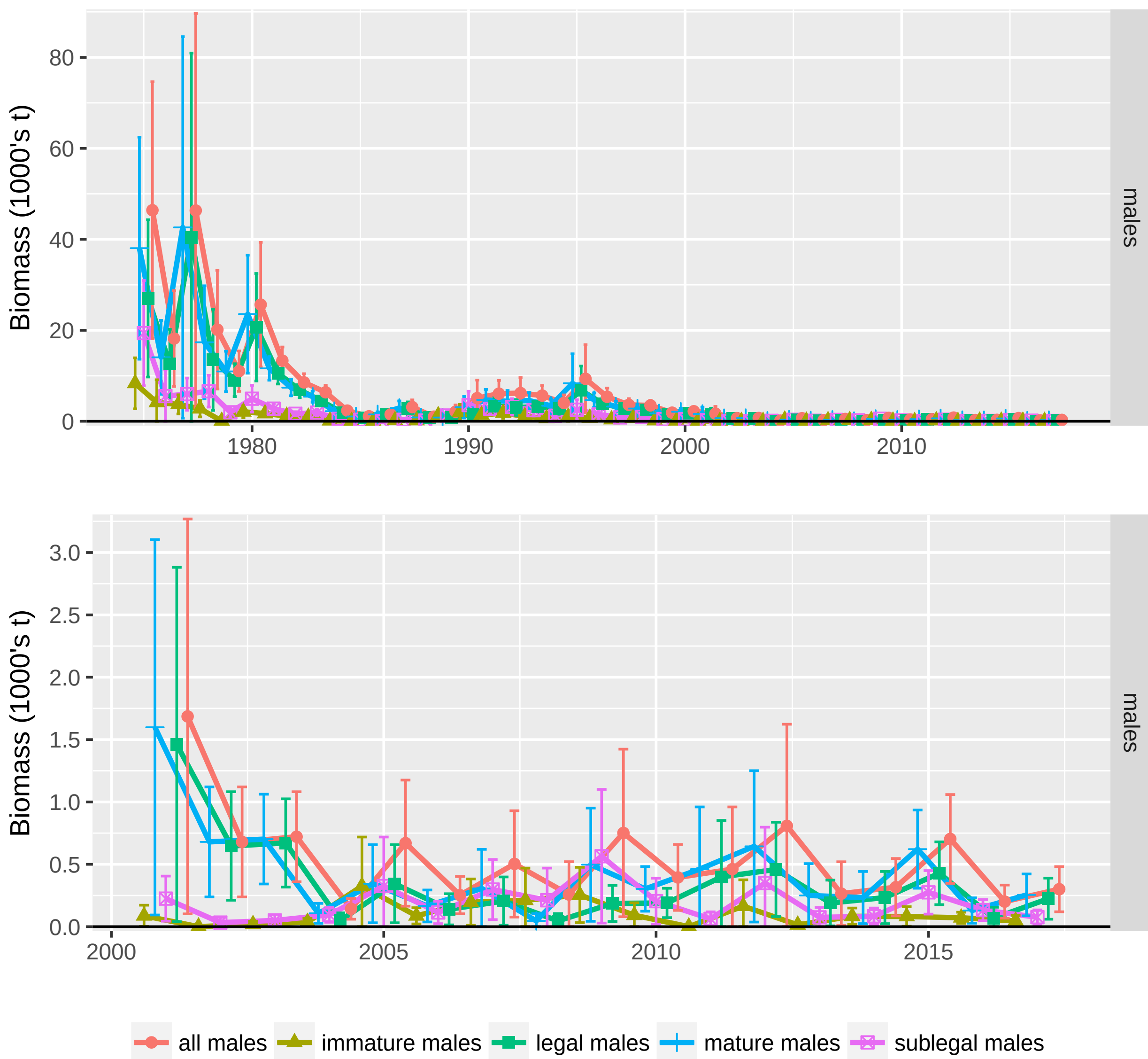

Figure 8: Time series of survey biomass for males in several categories (immature, mature, sublegal, legal and total).

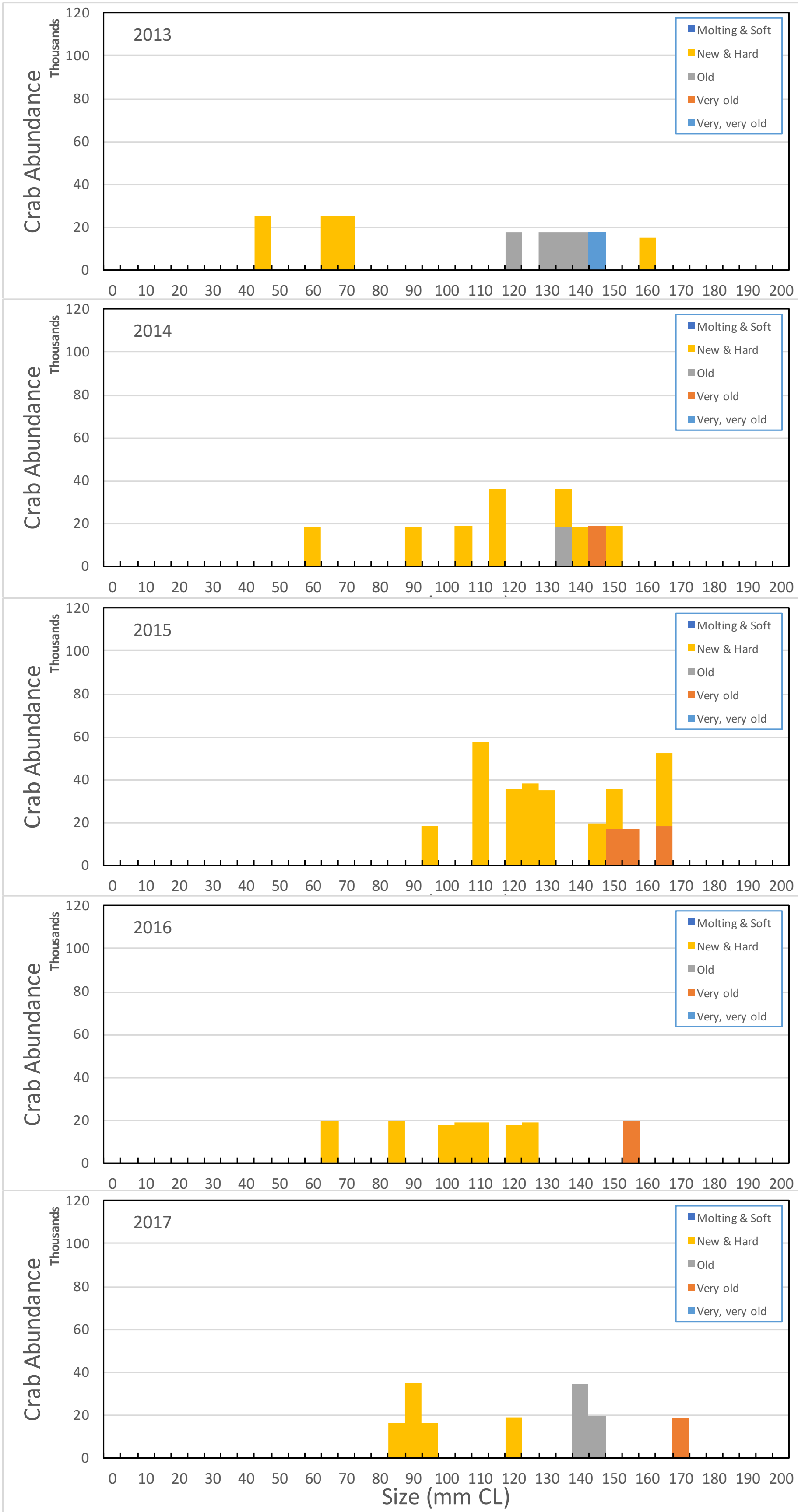

Figure 9: Size frequencies by shell condition for male Pribilof Island blue king crab in 5 mm length bins from recent NMFS EBS bottom trawl surveys.

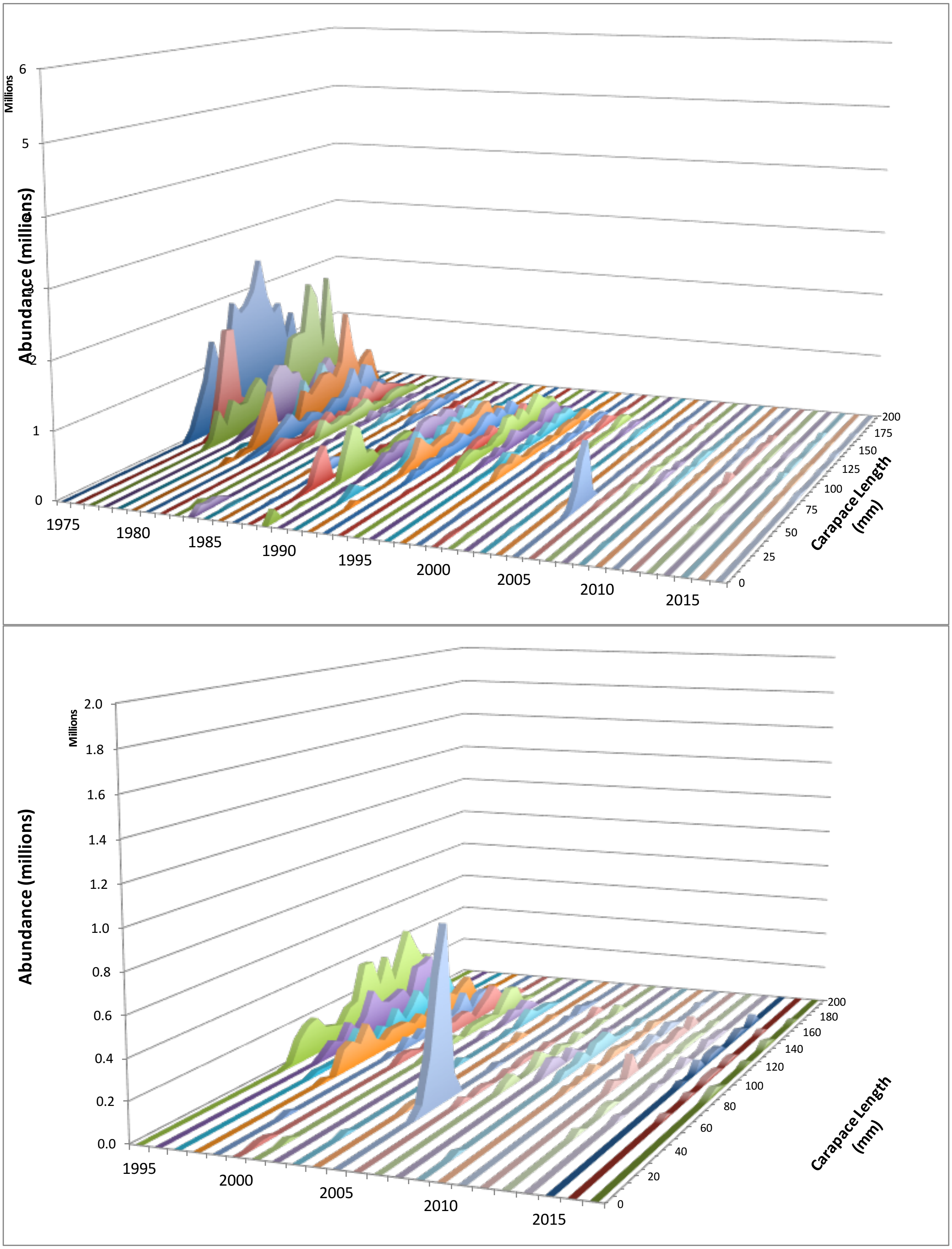

Figure 10: Size frequencies from the annual NMSF bottom trawl survey for male Pribilof Islands blue king crab by 5 mm length bins. The top row shows the entire time series, the bottom shows the size compositions since 1995.

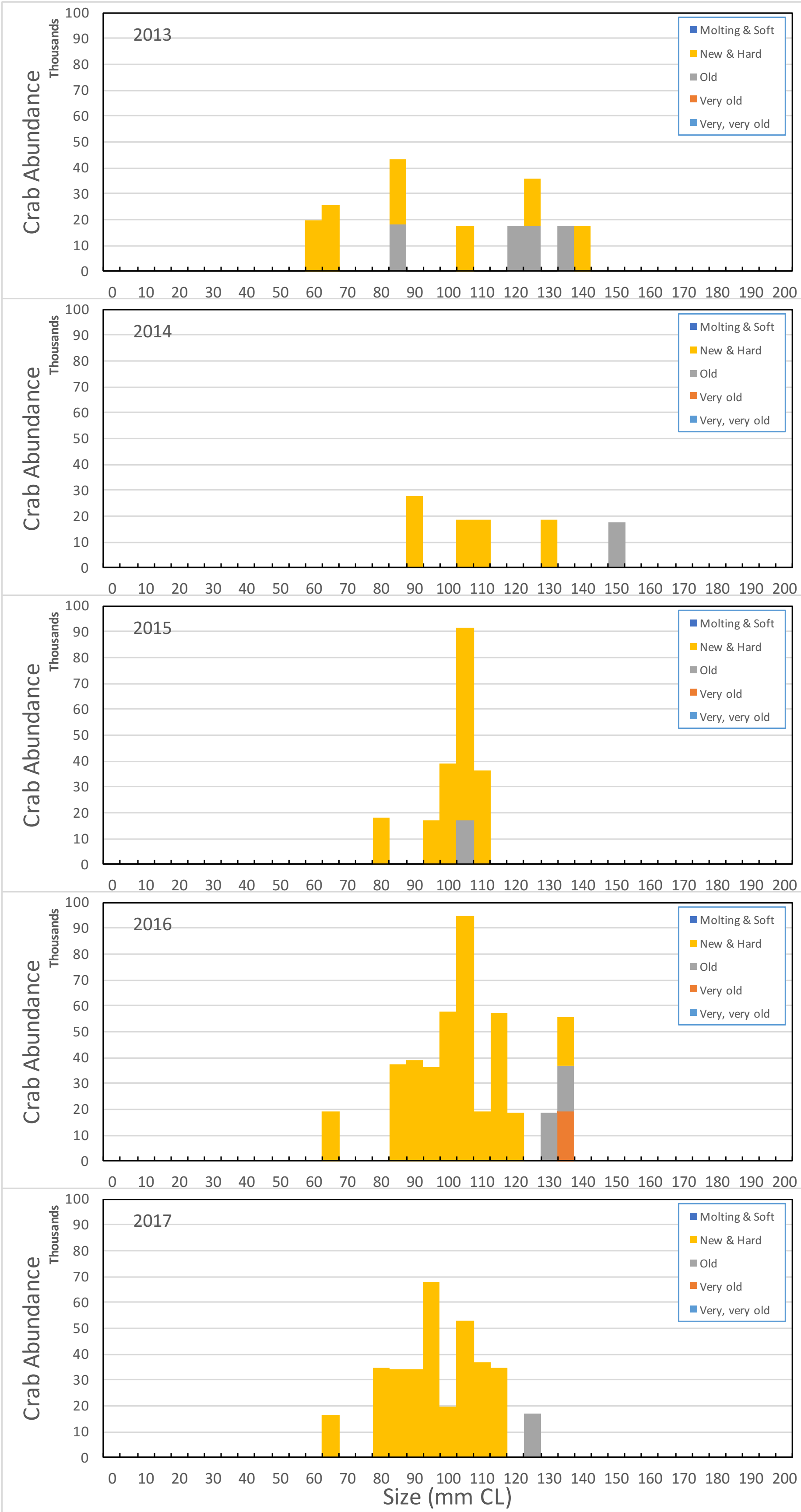

Figure 11: Size frequencies by shell condition for male Pribilof Island blue king crab in 5 mm length bins from recent NMFS EBS bottom trawl surveys.

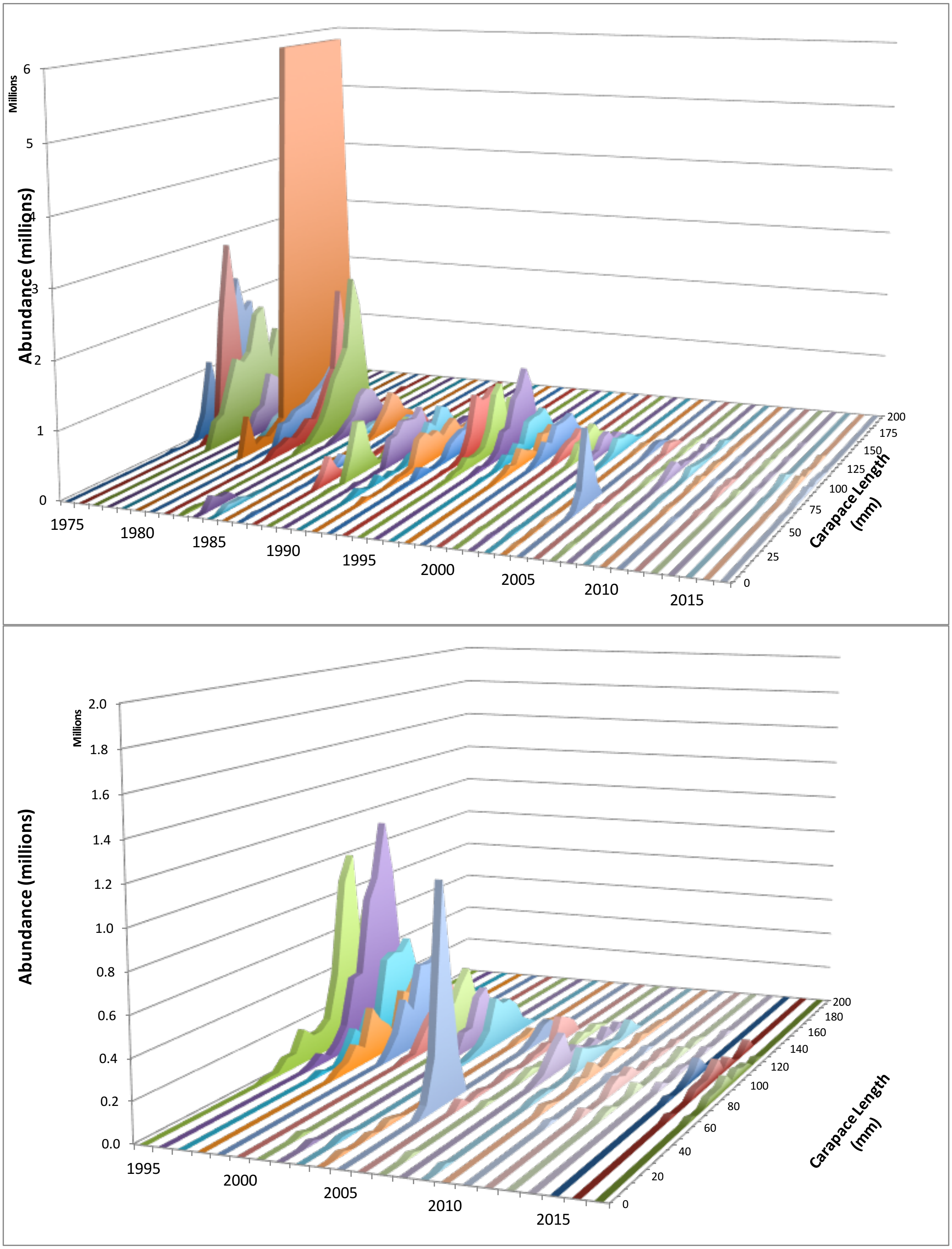

Figure 12: Size frequencies from the annual NMSF bottom trawl survey for male Pribilof Islands blue king crab by 5 mm length bins. The top row shows the entire time series, the bottom shows the size compositions since 1995.

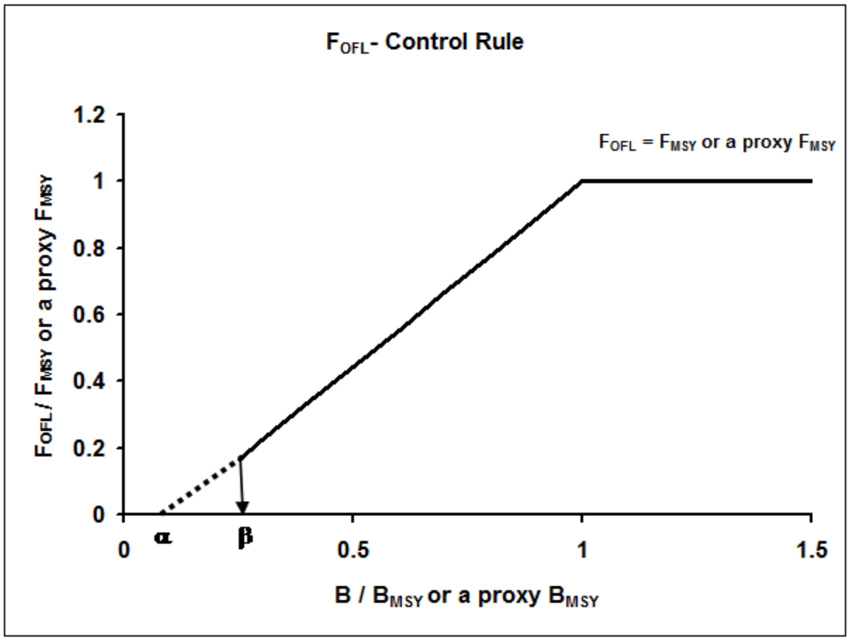

Figure 13: F_{OFL} Control Rule for Tier 4 stocks under Amendment 24 to the BSAI King and Tanner Crabs fishery management plan. Directed fishing mortality is set to 0 below β (= 0.25).

Appendix A: PIBKC Bycatch in the Groundfish Fisheries: 2009/10-2016/17

William Stockhausen

11 September, 2017

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Introduction

Bycatch of PIBKC in the groundfish fisheries during 2009/10-2016/17 was downloaded from AKFIN on Aug. 30, 2017 as file (“`FromAKFIN.PIBKC.BycatchEstimates.2009-2016.csv`”).

Bycatch by gear type

The bycatch of PIBKC by gear type (trawl or fixed) are presented in the following table. Catches using pelagic and non-pelagic trawl gear have been aggregated as "trawl" gear, while catches using hook-and-line (longline) and pot gear have been aggregated as "fixed" gear.

Table 1: Bycatch of PIBKC in the groundfish fisheries, by gear type. Biomass is in kilograms.

	fixed				trawl			
year	vessel count	haul count	biomass	number	vessel count	haul count	biomass	number
2009	4228	431820	216	87	2051	90347	207	193
2010	5415	609789	44	16	1858	38463	56	35
2011	4611	397979	112	54	1098	22300	7	8
2012	5024	502872	170	72	3785	69175	669	340
2013	8277	2172175	65	41	2247	35730	0	0
2014	8155	2026114	144	65	1899	58843	0	0
2015	7892	1470800	744	352	3198	68219	808	257
2016	5304	1189582	90	57	3280	53174	455	524

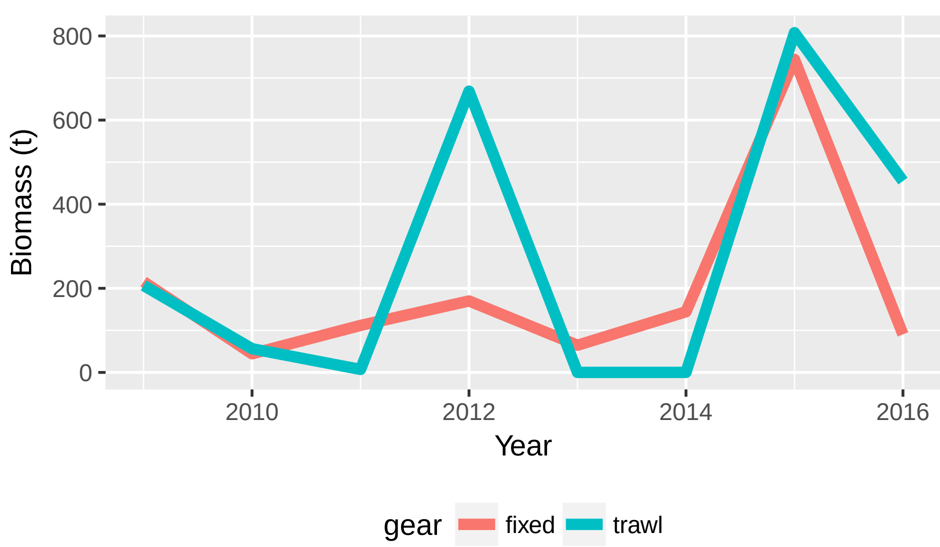

Figure 1: Bycatch of PIBKC in the groundfish fisheries by gear type.

Bycatch by target type

Bycatch of PIBKC in the groundfish fisheries is presented by groundfish target type in this section. Groundfish targets with less than 10 kg bycatch over the 2009-2016 period have been dropped from the table and figure.

Table 2: Bycatch of PIBKC in the groundfish fisheries by target type. Biomass is in kilograms.

	Flathead Sole		Pacific Cod		Rock Sole - BSAI		Yellowfin Sole - BSAI	
year	biomass	number	biomass	number	biomass	number	biomass	number
2009	71	54	216	87	0	0	129	119
2010	56	35	42	14	0	0	0	0
2011	0	0	119	62	0	0	0	0
2012	24	12	170	72	0	0	645	328
2013	0	0	64	41	0	0	0	0
2014	0	0	143	64	0	0	0	0
2015	147	58	742	351	0	0	661	199
2016	0	0	89	56	368	432	87	92

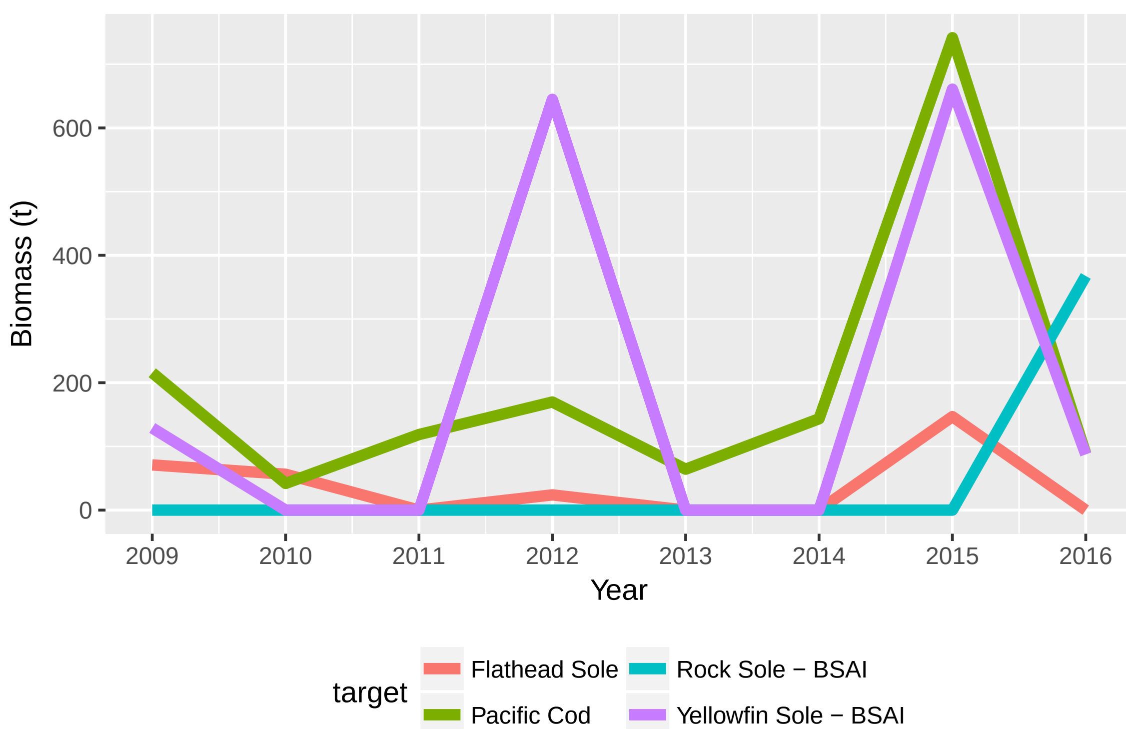

Figure 2: Bycatch of PIBKC in the groundfish fisheries, by target type.

Spatial patterns of bycatch

Spatial patterns of PIBKC bycatch, by ADFG stat area, in the groundfish fisheries are illustrated by gear type in Figures 4-5. All plots are on the same scale.

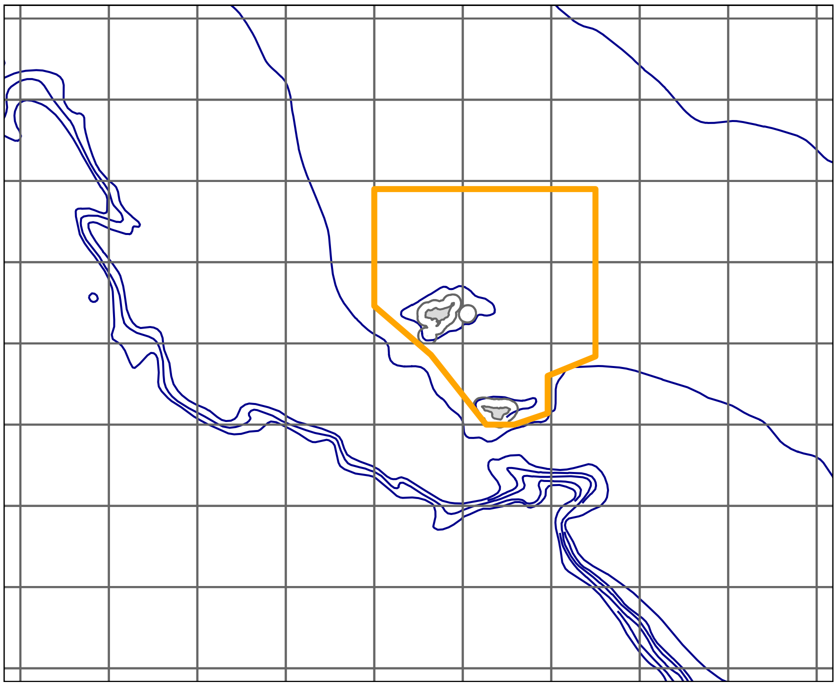

Figure 3: Basemap for subsequent maps, with EBS bathymetry (blue lines), ADFG stat areas (black rectangles), and the Pribilof Islands Habitat Conservation Area (orange outline).

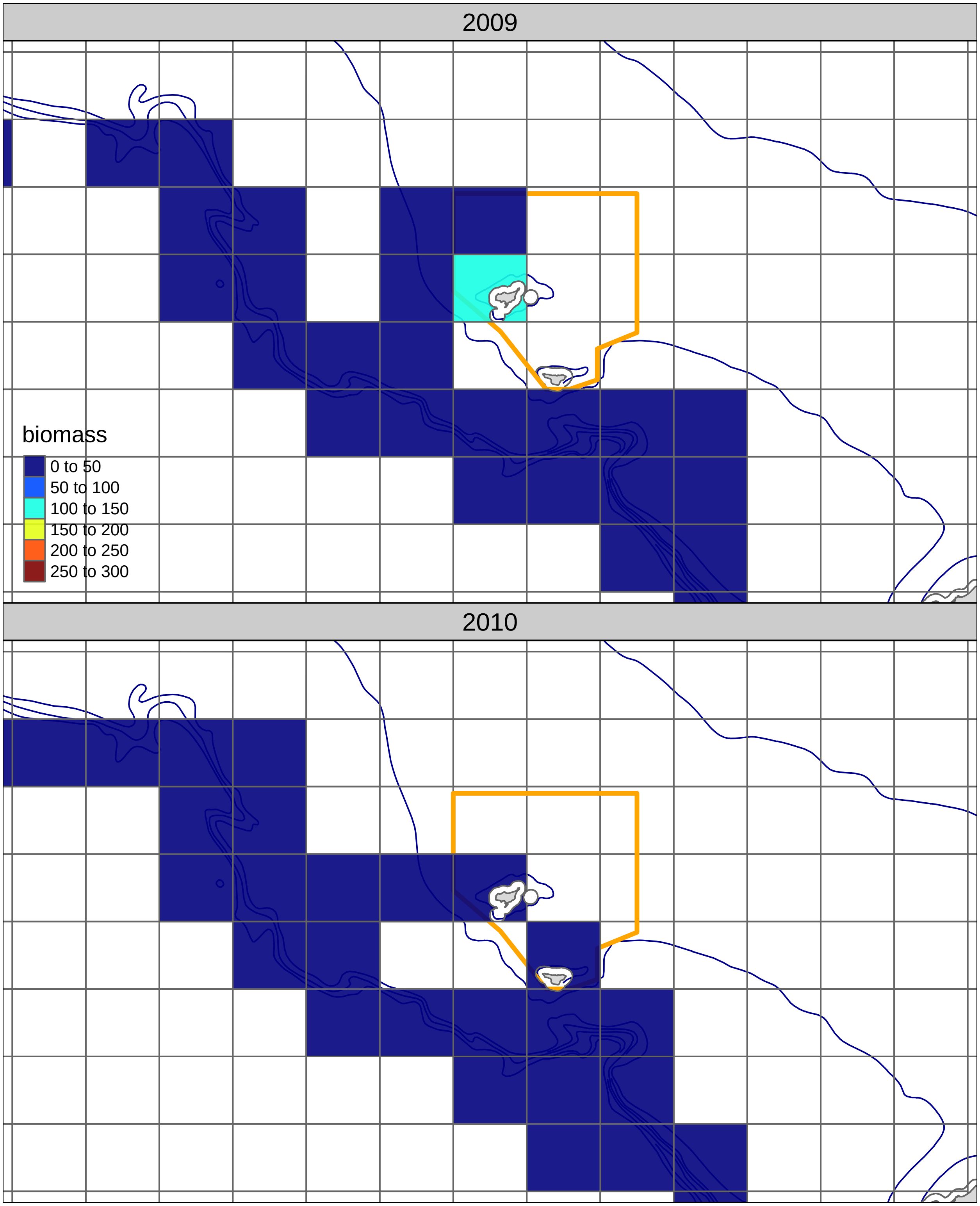

Figure 4: (1 of 4). Bycatch of PIBKC, by ADFG stat area, in the fixed gear groundfish fisheries.

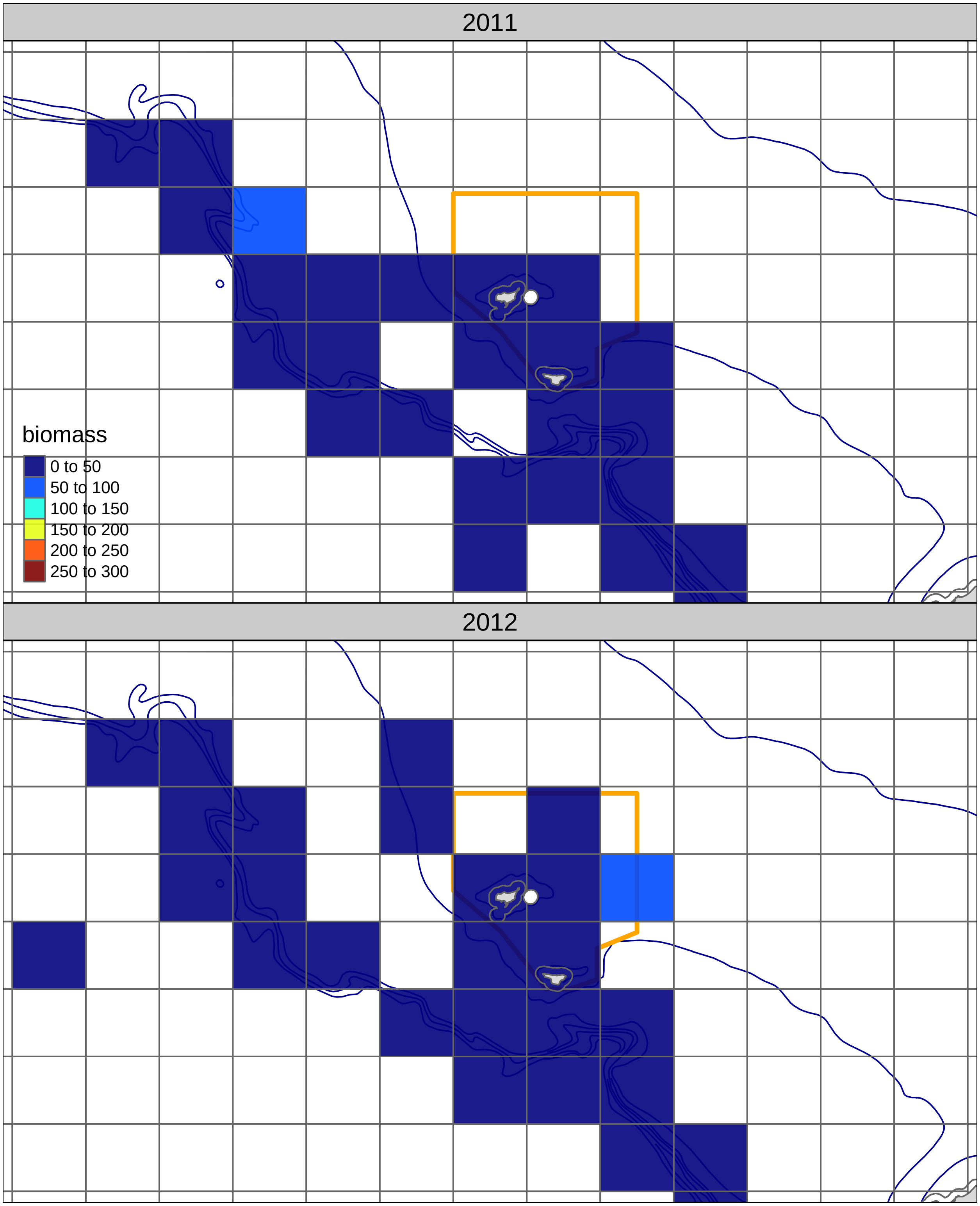

Figure 5: (2 of 4). Bycatch of PIBKC, by ADFG stat area, in the fixed gear groundfish fisheries.

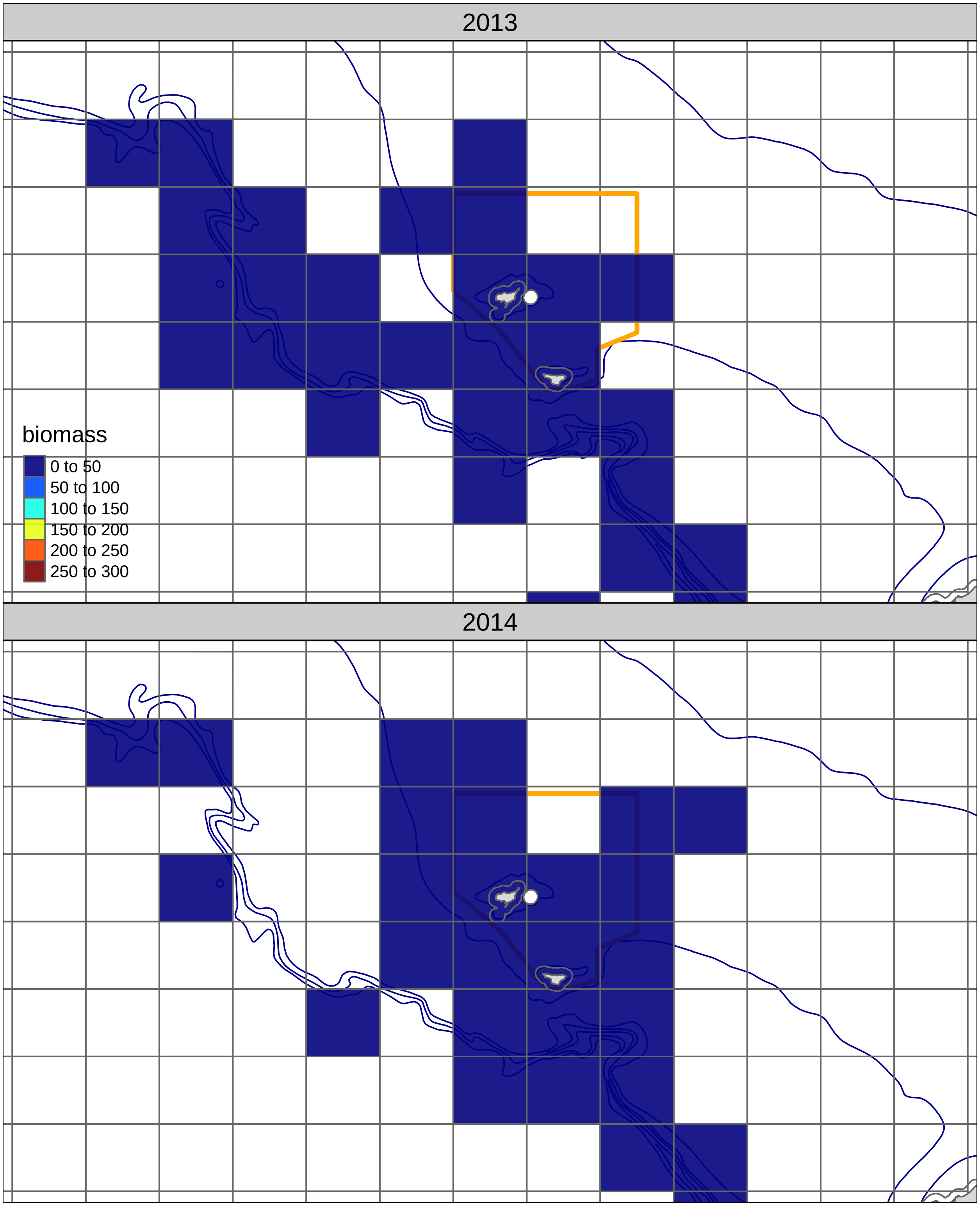

Figure 6: (3 of 4). Bycatch of PIBKC, by ADFG stat area, in the fixed gear groundfish fisheries.

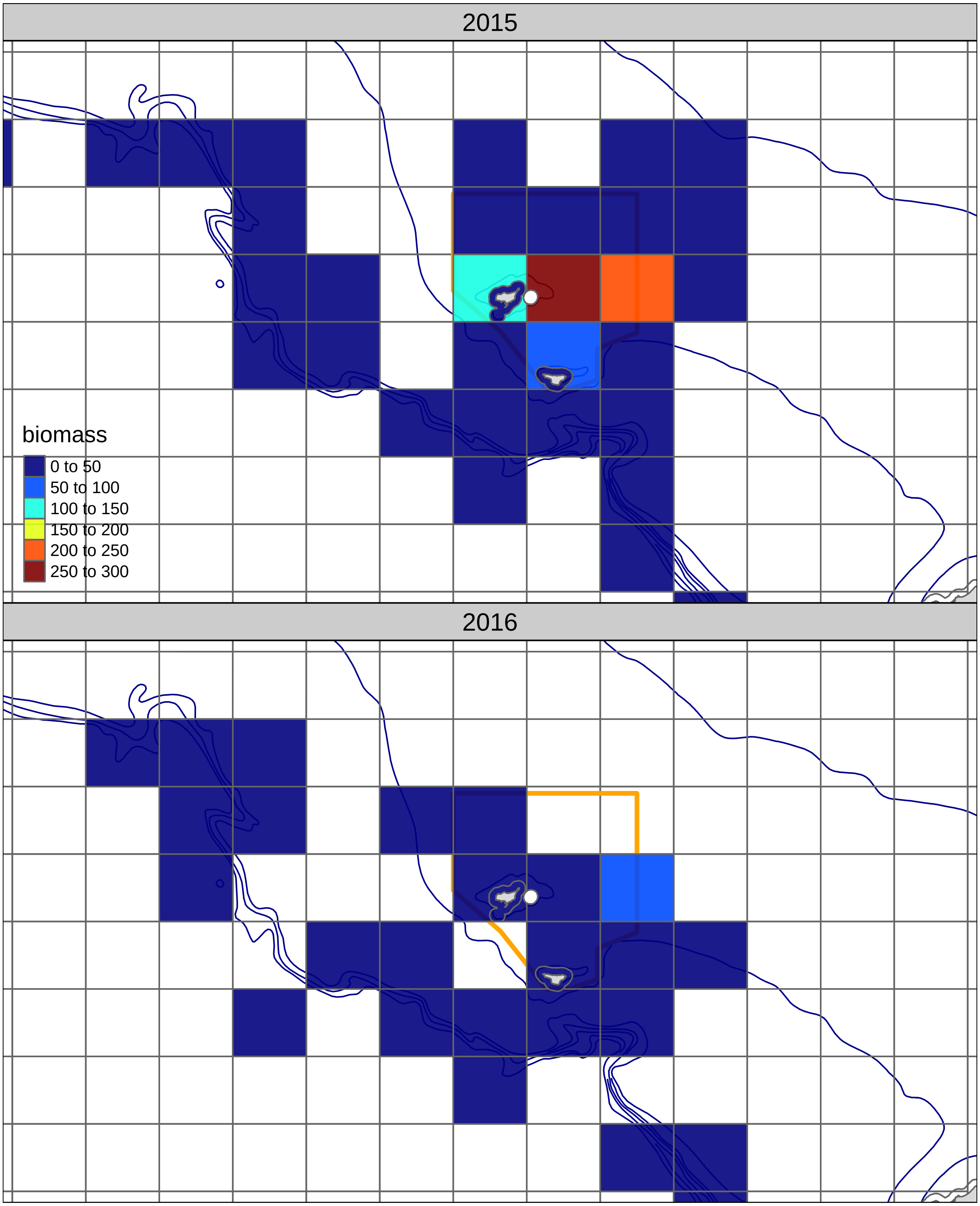

Figure 7: (4 of 4). Bycatch of PIBKC, by ADFG stat area, in the fixed gear groundfish fisheries.

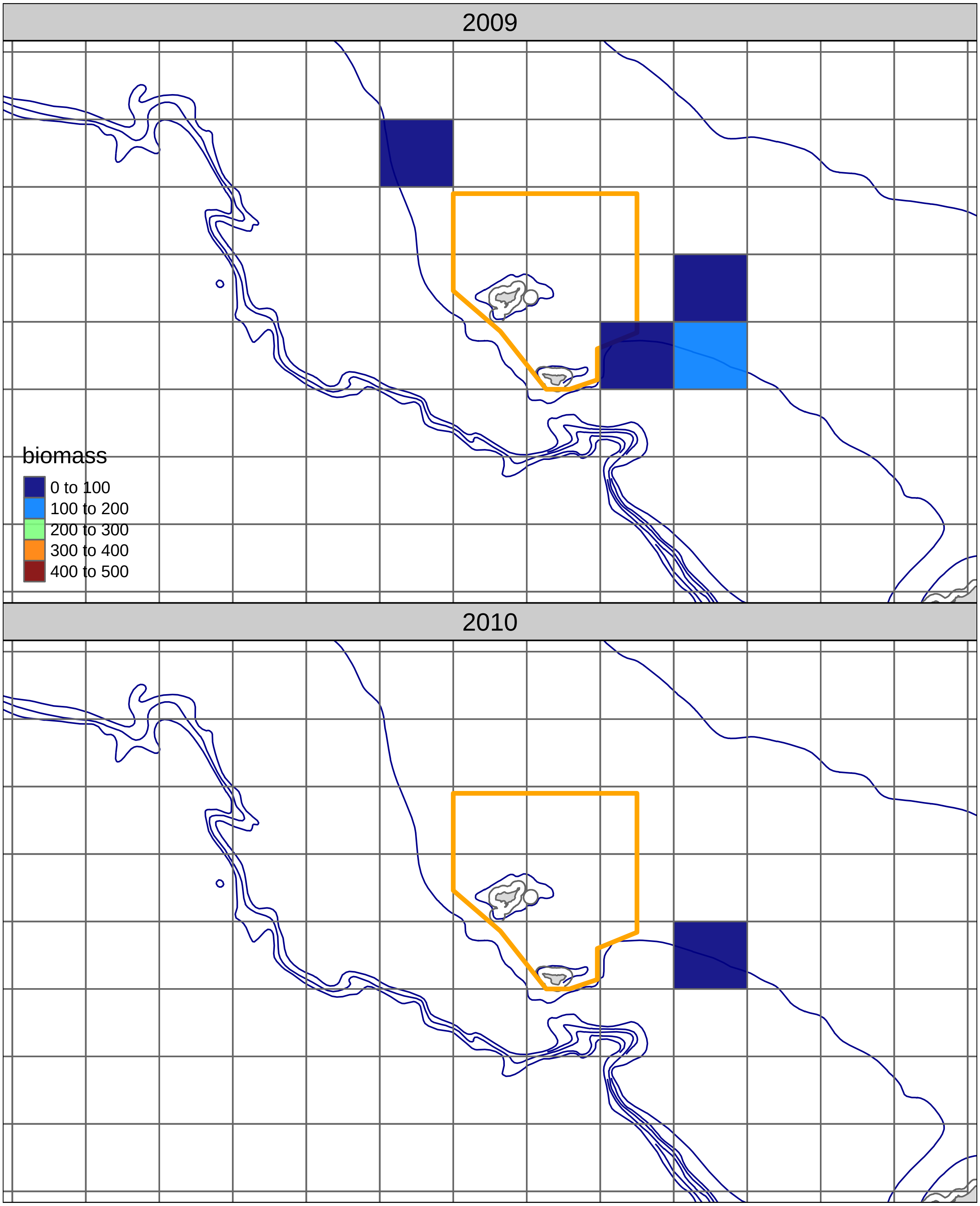

Figure 8: (1 of 4). Bycatch of PIBKC, by ADFG stat area, in the trawl gear groundfish fisheries.

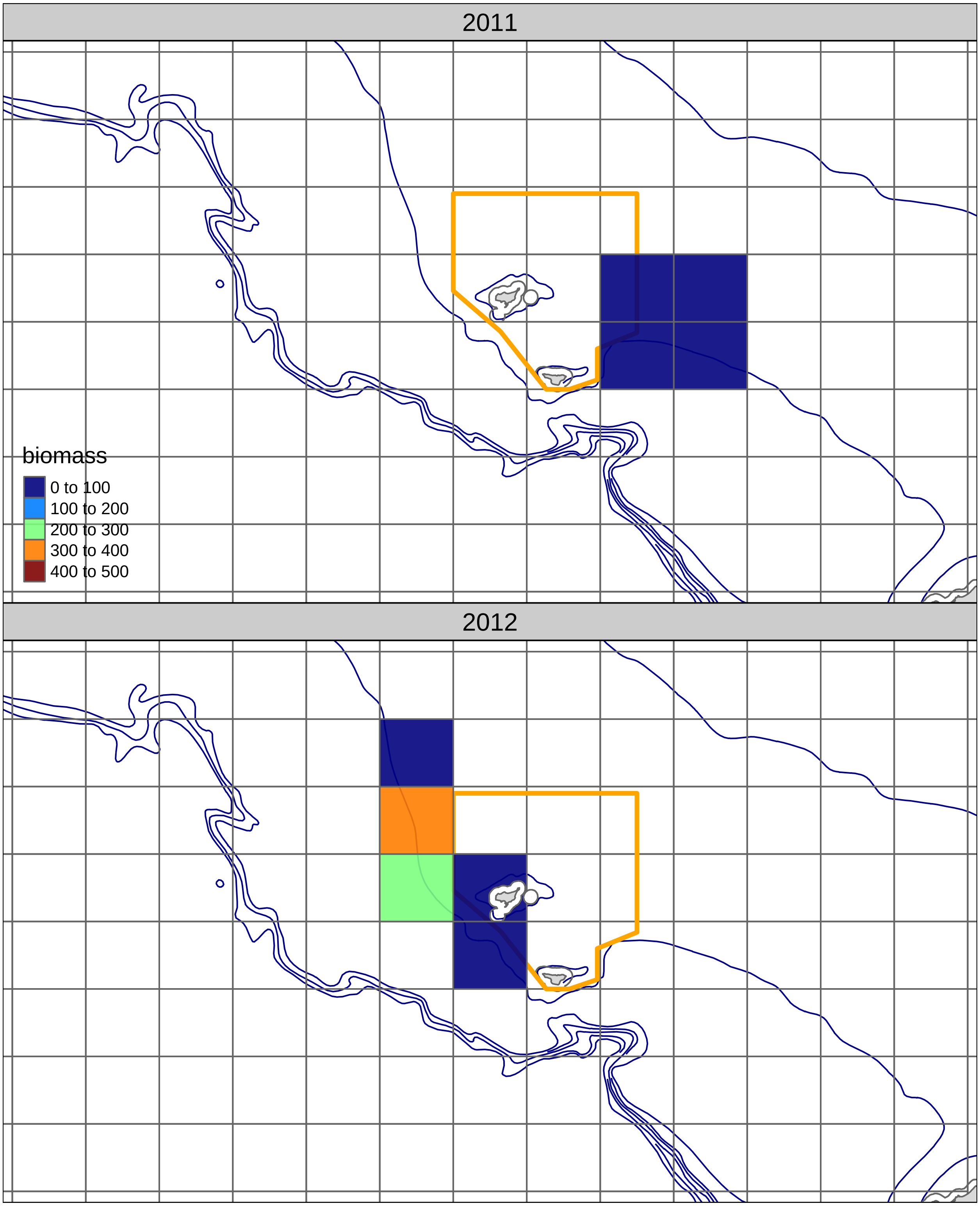

Figure 9: (2 of 4). Bycatch of PIBKC, by ADFG stat area, in the trawl gear groundfish fisheries.

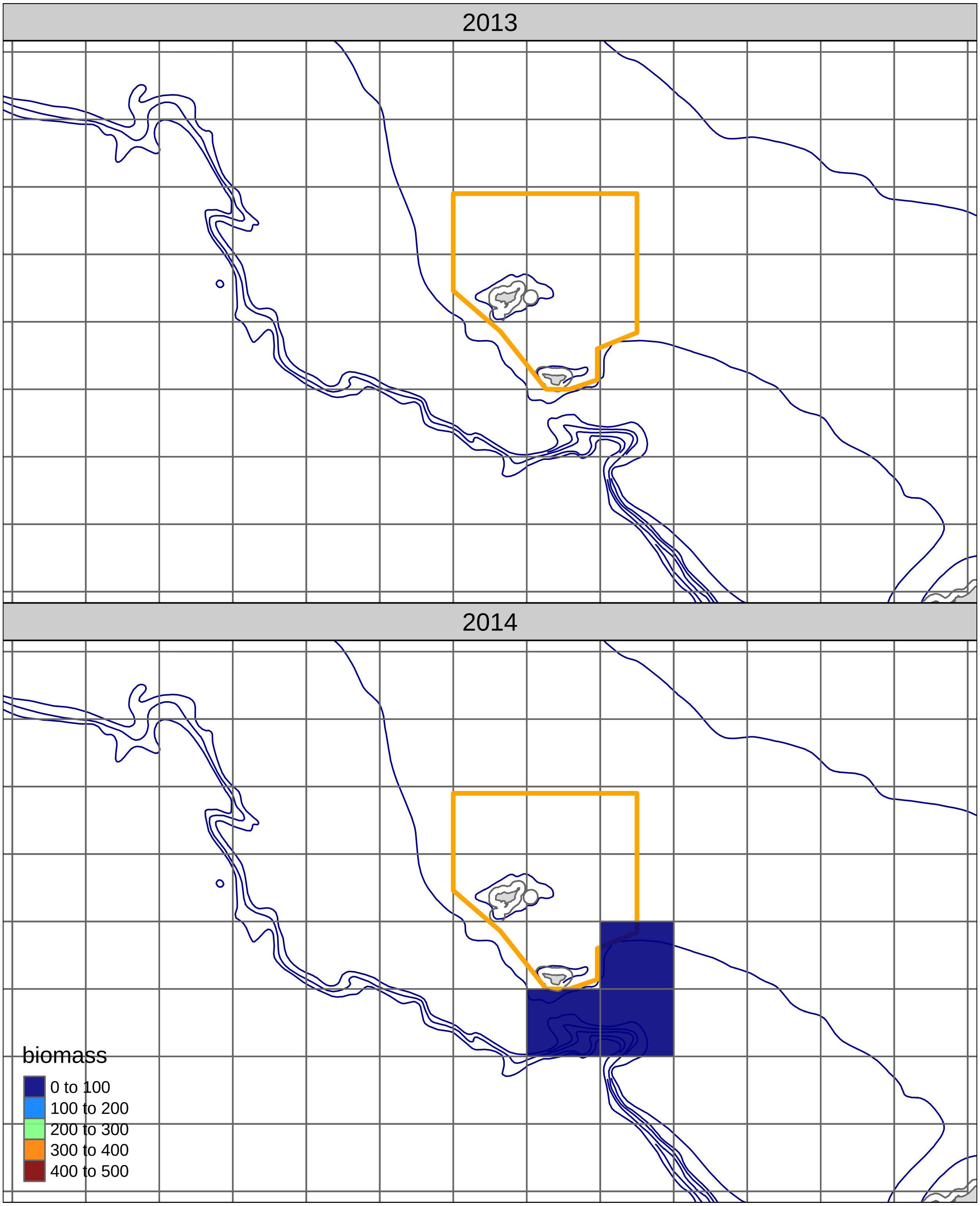

Figure 10: (3 of 4). Bycatch of PIBKC, by ADFG stat area, in the trawl gear groundfish fisheries.

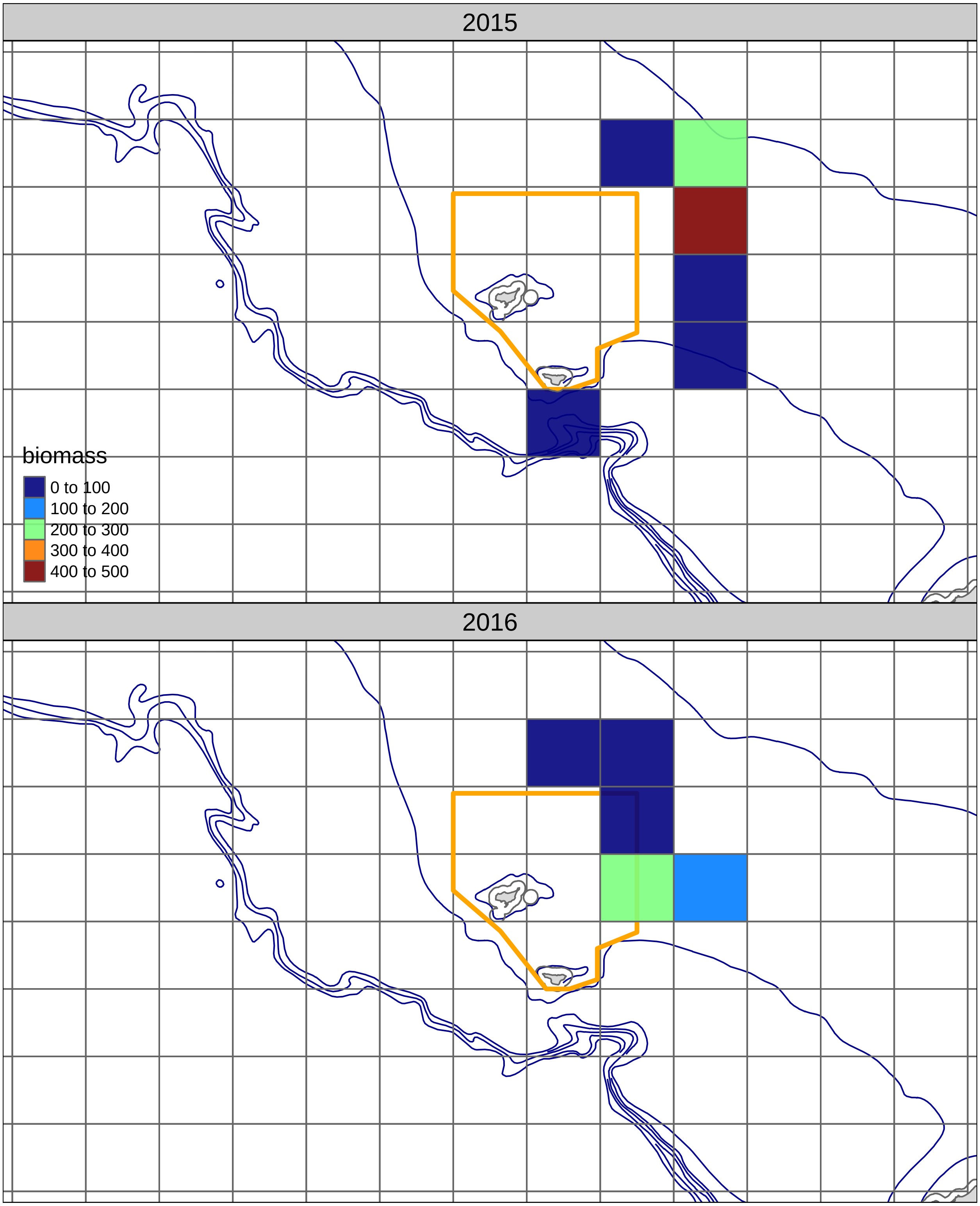

Figure 11: (4 of 4). Bycatch of PIBKC, by ADFG stat area, in the trawl gear groundfish fisheries.

Appendix B: NMFS Survey Data for the PIBKC Assessment

William Stockhausen

11 September, 2017

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Introduction

This report presents results from time series of aggregate abundance, biomass and size compositions from the annual NMFS EBS bottom trawl survey for Pribilof Islands blue king crab (PIBKC), i.e. blue king crab in the Pribilof District of the eastern Bering Sea (Figure 1), based on haul data and survey strata files downloaded from AKFIN on Aug. 30, 2017.

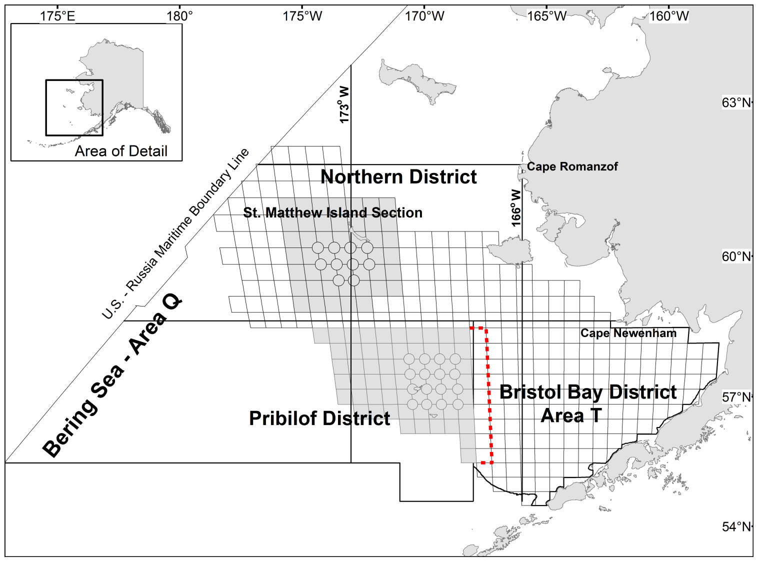

Figure 1: Map of the Pribilof District, which defines the stock area for the Pribilof Islands blue king crab stock. The grid indicates the locations of NMFS EBS survey stations.

Aggregate (abundance, biomass) time series were calculated for different components of the PIBKC stock, including immature and mature females and immature, mature, sublegal, and legal male crab based of the following size-based criteria:

Table 1: Size groupings for various components of the PIBKC stock used in this report.

sex	size.range	category
female	$<$ 100 mm CL	immature female
male	$<$ 120 mm CL	immature male
female	$>$ 99 mm CL	mature female
male	$>$ 119 mm CL	mature male
male	$<$ 135 mm CL	sublegal male
male	$>$ 134 mm CL	legal male
female	all	all females
male	all	all males

Annual survey abundance and biomass

Annual survey abundance and biomass for PIBKC were calculated from the survey haul data as if the survey were conducted using a random-stratified sampling design (it uses a fixed grid).

The following plots illustrate time series trends in Tanner crab survey abundance and biomass by sex and area.

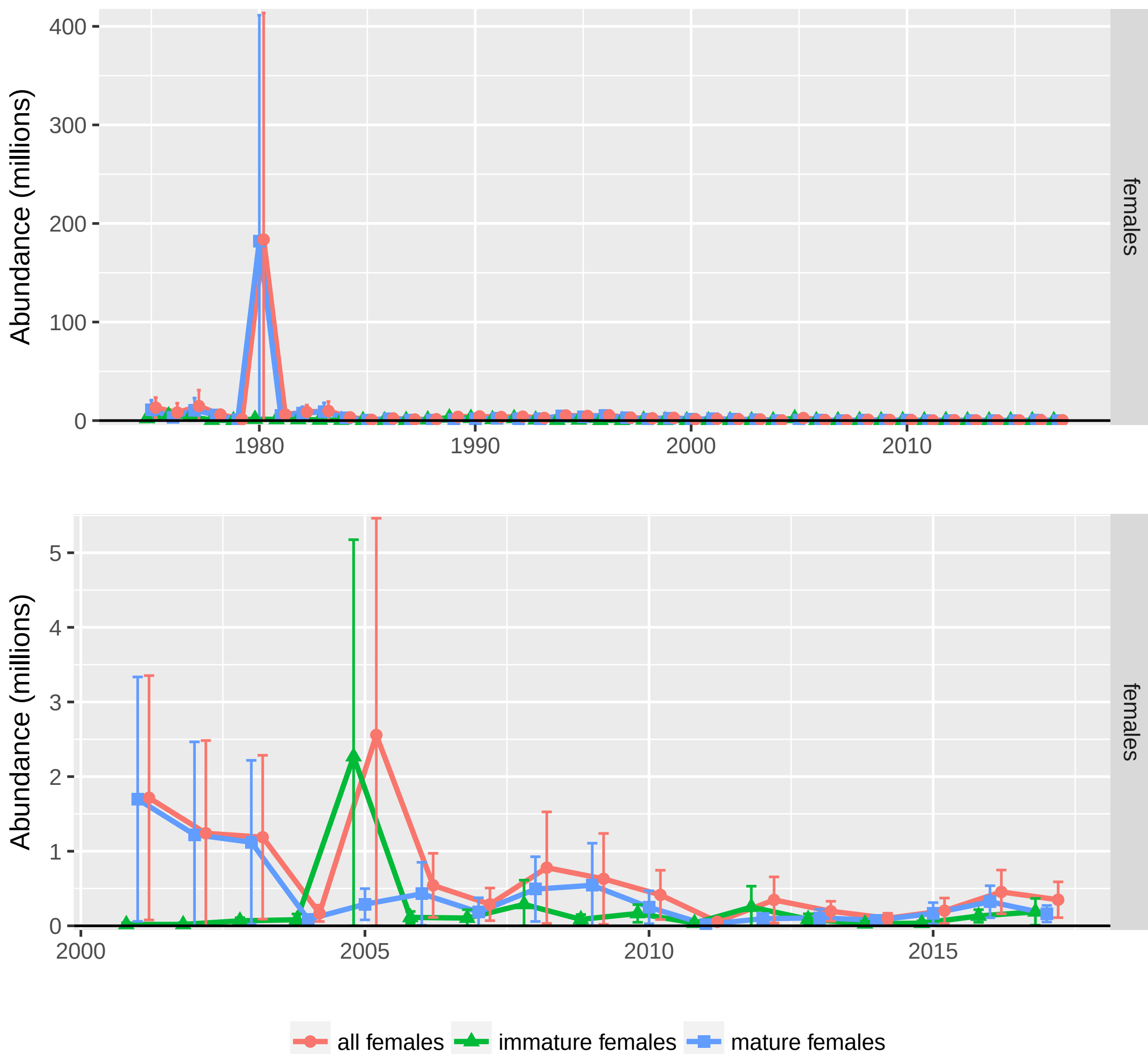

Figure 2: NMFS survey abundance time series for female PIBKC. Upper plot is entire time series, lower plot since 2001.

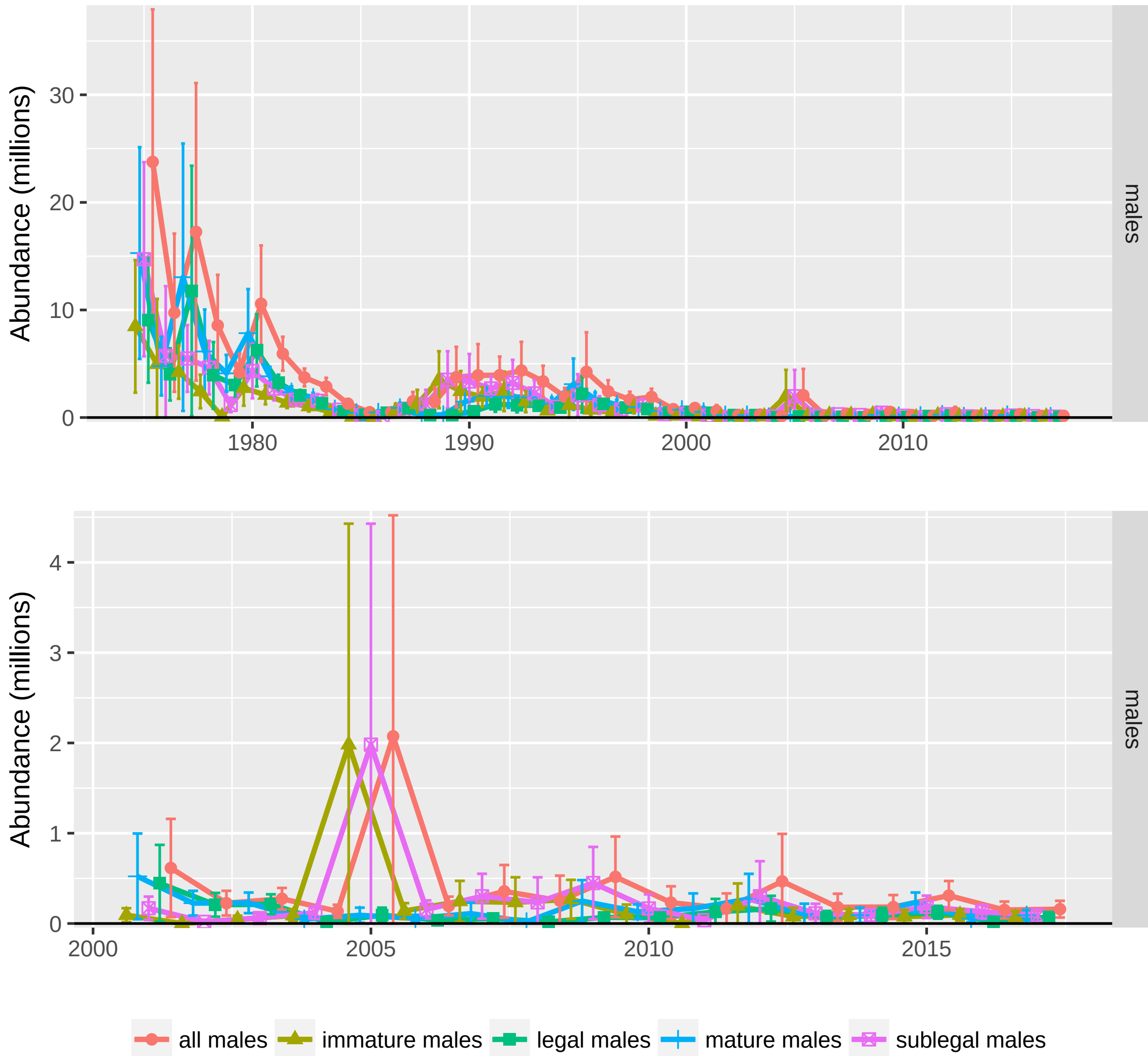

Figure 3: NMFS survey abundance time series for male PIBKC. Upper plot is entire time series, lower plot since 2001.

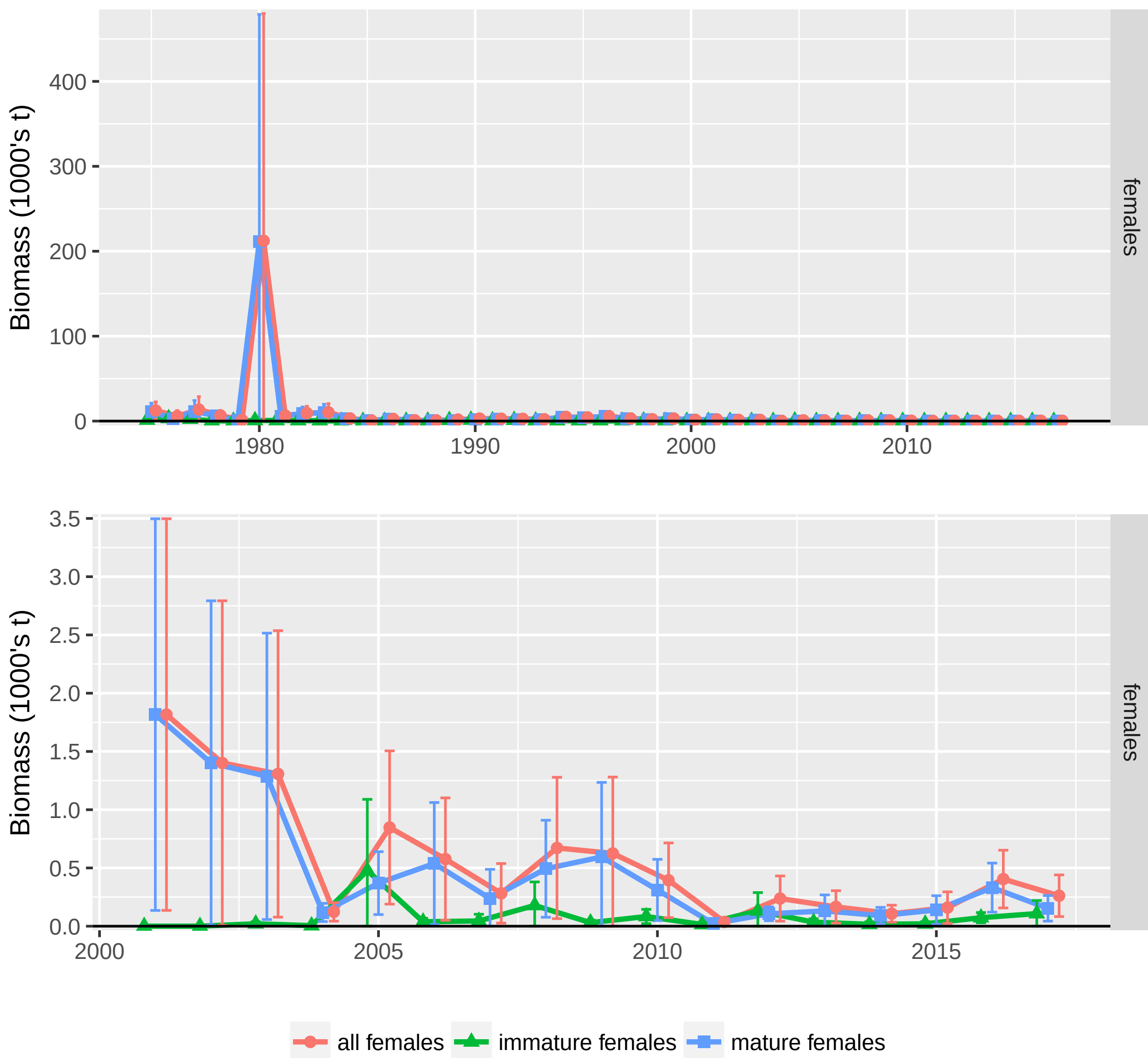

Figure 4: NMFS survey biomass time series for female PIBKC. Upper plot is entire time series, lower plot since 2001.

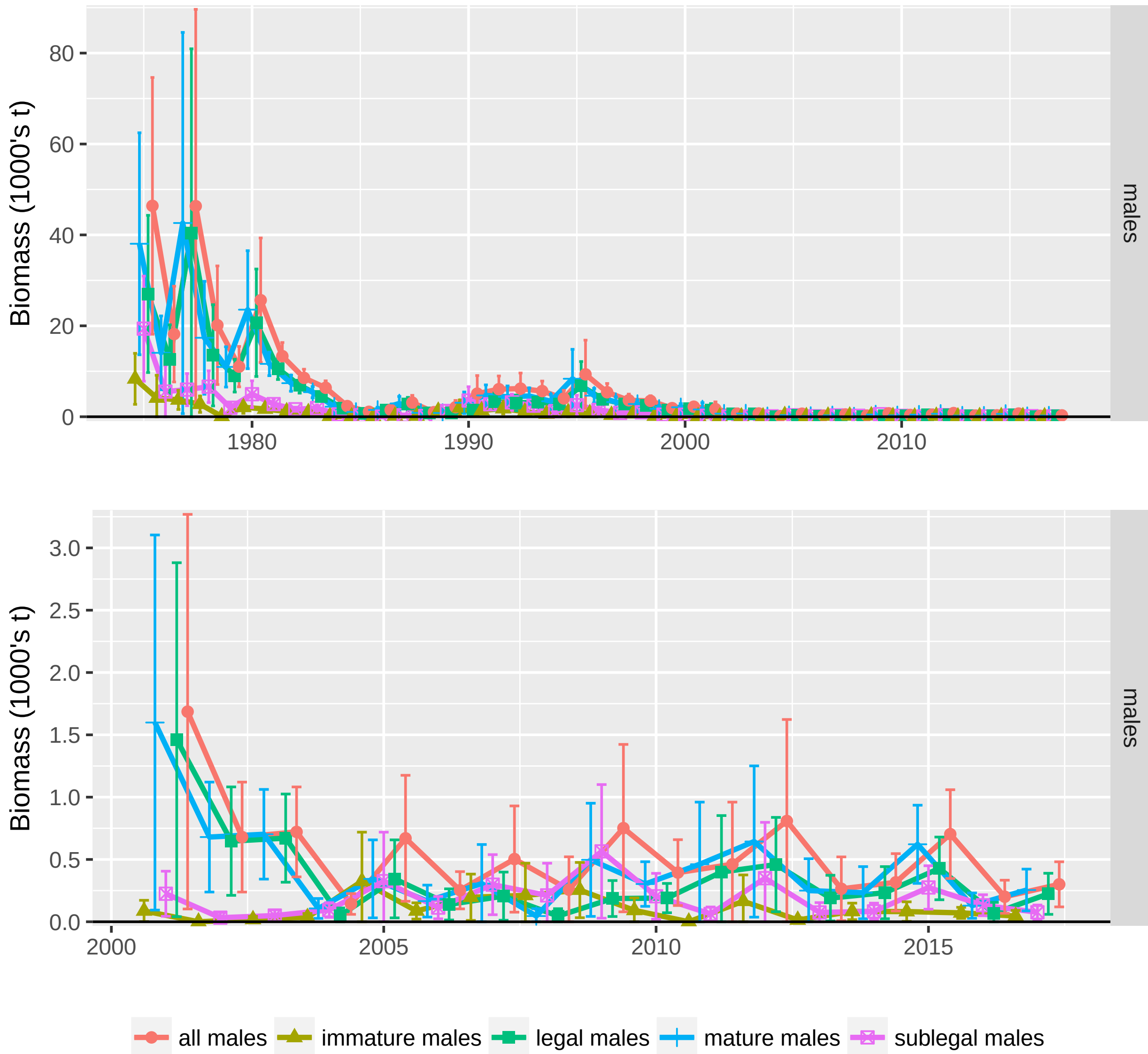

Figure 5: NMFS survey biomass time series for male PIBKC. Upper plot is entire time series, lower plot since 2001.

The following two tables document the annual sampling effort (the number of survey hauls, the number of survey hauls with non-zero catch, and the number of crab caught) by the NMFS bottom trawl survey in the Pribilof District by PIBKC population category.

Table 2: Sample sizes (number of survey hauls, number hauls where crab were caught, number of crab caught) for the NMFS EBS trawl survey in the Pribilof District each year, for female population components.

	survey	immature females		mature females		all females	
	number	non-0	no.	non-0	no.	non-0	no.
year	of hauls	hauls	crab	hauls	crab	hauls	crab
1975	45	6	72	7	193	9	265
1976	59	2	55	5	37	5	92
1977	58	3	45	5	100	5	145
1978	58	4	11	8	97	8	108
1979	58	3	4	3	21	5	25
1980	70	8	17	10	326	11	343
1981	84	16	49	19	184	23	233
1982	84	11	49	22	250	24	299
1983	86	8	23	16	280	18	303
1984	86	7	27	14	142	15	169
1985	86	7	15	8	28	12	43
1986	86	2	2	8	106	10	108
1987	86	5	23	7	35	11	58
1988	85	6	41	7	17	9	58
1989	86	8	144	9	27	13	171
1990	86	7	88	9	77	10	165
1991	85	10	57	12	105	15	162
1992	86	6	83	9	59	11	142
1993	85	8	46	13	88	15	134
1994	86	6	25	12	254	13	279
1995	86	5	43	11	215	12	258
1996	86	6	13	10	213	12	226
1997	86	4	17	11	137	13	154
1998	85	9	44	11	92	15	136
1999	86	3	10	10	145	10	155
2000	85	2	2	13	72	13	74
2001	86	1	1	9	93	10	94
2002	86	1	1	6	66	7	67
2003	86	4	4	7	69	9	73
2004	85	2	4	4	5	5	9
2005	84	1	43	5	15	6	58
2006	86	4	6	3	22	6	28
2007	86	2	6	3	10	5	16
2008	86	3	16	4	27	6	43
2009	86	3	5	3	33	4	38
2010	86	5	9	4	15	7	24
2011	86	2	2	1	1	3	3
2012	86	2	11	5	5	6	16
2013	86	3	4	2	6	5	10
2014	86	1	1	3	4	4	5
2015	86	2	2	4	9	4	11
2016	86	5	7	7	17	8	24
2017	86	3	7	4	8	6	15

Table 3: Sample sizes (number of survey hauls, number hauls where crab were caught, number of crab caught) for the NMFS EBS trawl survey in the Pribilof District each year, for male population components.

	survey	immature males		mature males		sublegal males		legal males		all males	
	number	non-0	no.	non-0	no.	non-0	no.	non-0	no.	non-0	no.
year	of hauls	hauls	crab	hauls	crab	hauls	crab	hauls	crab	hauls	crab
1975	45	11	305	13	553	11	530	13	328	13	858
1976	59	3	105	11	91	9	122	10	74	12	196
1977	58	7	56	10	129	9	73	9	112	10	185
1978	58	8	60	11	130	10	112	10	78	12	190
1979	58	2	2	14	90	8	25	13	67	14	92
1980	70	10	41	21	133	12	64	21	110	21	174
1981	84	19	99	36	184	23	128	36	155	38	283
1982	84	19	70	35	114	21	84	31	100	38	184
1983	86	15	47	32	93	18	74	29	66	35	140
1984	86	10	27	20	37	17	37	16	27	25	64
1985	86	3	4	14	24	8	13	11	15	14	28
1986	86	1	1	13	26	2	2	13	25	13	27
1987	86	5	34	15	50	6	38	14	46	16	84
1988	85	5	52	5	12	5	52	5	12	9	64
1989	86	8	160	4	11	8	160	4	11	10	171
1990	86	8	90	10	59	11	126	7	23	14	149
1991	85	16	92	19	103	20	129	14	66	22	195
1992	86	12	89	14	73	13	119	12	43	17	162
1993	85	12	75	19	96	15	115	17	56	21	171
1994	86	8	32	18	68	12	51	18	49	19	100
1995	86	7	66	18	177	15	118	14	125	19	243
1996	86	7	32	19	87	11	54	19	65	20	119
1997	86	7	25	17	65	10	39	16	51	19	90
1998	85	12	56	20	56	15	66	17	46	21	112
1999	86	7	9	13	34	9	18	11	25	15	43
2000	85	4	9	16	40	9	20	13	29	16	49
2001	86	3	5	6	28	4	9	5	24	7	33
2002	86	0	0	6	12	1	1	6	11	6	12
2003	86	2	2	7	14	3	3	7	13	9	16
2004	85	3	5	3	3	5	7	1	1	6	8
2005	84	3	54	2	5	3	54	2	5	4	59
2006	86	4	7	3	3	4	8	2	2	6	10
2007	86	4	14	2	6	4	17	2	3	4	20
2008	86	2	13	1	1	2	13	1	1	3	14
2009	86	5	16	3	15	5	27	3	4	5	31
2010	86	2	6	5	8	3	10	4	4	5	14
2011	86	0	0	3	9	2	2	2	7	3	9
2012	86	1	9	4	13	1	14	4	8	4	22
2013	86	1	3	2	6	2	5	2	4	3	9
2014	86	3	5	2	5	3	5	2	5	4	10
2015	86	2	4	8	13	6	10	5	7	9	17
2016	86	4	5	3	3	5	7	1	1	5	8
2017	86	2	4	4	4	3	5	3	3	5	8

The following two tables document the estimated annual PIBKC abundance and associated uncertainty (as the coefficient of variation) in the NMFS bottom trawl survey by PIBKC populaton category. The estimated abundance and uncertainity for each category is calculated using a swept-area approach as if the EBS trawl survey were conducted using a stratified-random sampling design, rather than as a grid-based design. While re-calculated from the "raw" survey data using a completely independent approach, the estimates are the same (to 4 or 5 decimal places) as those provided in the annual survey Technical Memoranda.

Table 4: Estimated annual abundance of female PIBKC population components from the NMFS EBS trawl survey.

	immature females		mature females		all females	
	abundance	cv	abundance	cv	abundance	cv
year	millions		millions		millions	
1975	2.127	0.740	11.020	0.687	13.148	0.608
1976	5.001	0.956	3.138	0.838	8.139	0.910
1977	4.064	0.786	10.667	0.890	14.732	0.857
1978	0.494	0.603	5.493	0.684	5.987	0.656
1979	0.178	0.604	1.133	0.838	1.311	0.767
1980	1.498	0.477	182.186	0.981	183.684	0.976
1981	1.176	0.296	5.084	0.482	6.260	0.423
1982	1.162	0.415	7.551	0.671	8.713	0.626
1983	0.691	0.673	9.080	0.771	9.772	0.763
1984	0.522	0.467	2.713	0.382	3.235	0.366
1985	0.260	0.541	0.486	0.437	0.746	0.360
1986	0.037	0.698	2.102	0.898	2.139	0.882
1987	0.420	0.754	0.652	0.599	1.072	0.478
1988	0.972	0.804	0.391	0.471	1.363	0.642
1989	2.991	0.669	0.787	0.533	3.778	0.576
1990	2.502	0.775	1.721	0.474	4.223	0.555
1991	1.343	0.455	2.230	0.389	3.573	0.353
1992	2.277	0.758	1.670	0.459	3.947	0.521
1993	0.911	0.567	1.752	0.441	2.663	0.378
1994	0.503	0.681	4.689	0.448	5.192	0.437
1995	0.751	0.808	3.946	0.521	4.697	0.491
1996	0.289	0.460	5.033	0.486	5.322	0.463
1997	0.320	0.669	2.614	0.423	2.935	0.388
1998	0.747	0.428	1.583	0.473	2.330	0.365
1999	0.172	0.789	2.584	0.477	2.756	0.490
2000	0.035	0.698	1.328	0.465	1.363	0.463
2001	0.019	1.000	1.697	0.753	1.716	0.745
2002	0.019	1.000	1.222	0.794	1.241	0.782
2003	0.067	0.483	1.120	0.764	1.188	0.721
2004	0.081	0.740	0.087	0.517	0.168	0.510
2005	2.268	1.000	0.289	0.565	2.557	0.886
2006	0.113	0.548	0.430	0.766	0.543	0.617
2007	0.104	0.842	0.184	0.813	0.288	0.592
2008	0.287	0.881	0.492	0.688	0.779	0.748
2009	0.086	0.585	0.543	0.811	0.629	0.755
2010	0.166	0.558	0.249	0.691	0.415	0.622
2011	0.037	0.698	0.018	1.000	0.055	0.563
2012	0.251	0.873	0.096	0.426	0.347	0.695
2013	0.089	0.637	0.107	0.846	0.196	0.534
2014	0.028	1.000	0.074	0.604	0.102	0.507
2015	0.035	0.699	0.167	0.671	0.202	0.655
2016	0.132	0.504	0.323	0.519	0.454	0.504
2017	0.188	0.746	0.162	0.533	0.350	0.535

Table 5: Estimated annual abundance of male PIBKC population components from the NMFS EBS trawl survey.

	immature males		mature males		sublegal males		legal males		all males	
	abundance	cv	abundance	cv	abundance	cv	abundance	cv	abundance	cv
year	millions		millions		millions		millions		millions	
1975	8.476	0.567	15.288	0.502	14.712	0.479	9.051	0.501	23.764	0.466
1976	4.960	0.954	4.782	0.445	5.729	0.882	4.012	0.471	9.742	0.589
1977	4.216	0.457	13.044	0.743	5.491	0.440	11.769	0.771	17.260	0.625
1978	2.421	0.502	6.141	0.496	4.639	0.419	3.923	0.616	8.562	0.428
1979	0.079	0.704	4.108	0.326	1.170	0.449	3.017	0.310	4.187	0.324
1980	2.733	0.466	7.842	0.408	4.331	0.458	6.244	0.420	10.575	0.400
1981	2.099	0.324	3.834	0.180	2.688	0.317	3.246	0.177	5.934	0.207
1982	1.371	0.281	2.354	0.181	1.654	0.255	2.071	0.188	3.725	0.172
1983	1.031	0.357	1.851	0.186	1.561	0.309	1.321	0.170	2.882	0.220
1984	0.518	0.397	0.771	0.225	0.730	0.290	0.558	0.247	1.288	0.212
1985	0.068	0.598	0.428	0.281	0.226	0.340	0.270	0.294	0.496	0.269
1986	0.019	1.000	0.480	0.305	0.039	0.698	0.460	0.313	0.499	0.298
1987	0.622	0.834	0.903	0.414	0.695	0.748	0.830	0.416	1.525	0.434
1988	1.238	0.842	0.238	0.509	1.238	0.842	0.238	0.509	1.476	0.708
1989	3.515	0.588	0.240	0.624	3.515	0.588	0.240	0.624	3.755	0.585
1990	2.450	0.596	1.470	0.626	3.349	0.596	0.572	0.538	3.920	0.578
1991	1.920	0.373	2.014	0.363	2.697	0.332	1.238	0.444	3.935	0.343
1992	2.436	0.588	1.935	0.420	3.217	0.520	1.154	0.453	4.371	0.475
1993	1.484	0.520	1.876	0.310	2.245	0.432	1.114	0.300	3.359	0.339
1994	0.639	0.374	1.294	0.341	0.998	0.343	0.935	0.345	1.933	0.332
1995	1.147	0.889	3.102	0.600	2.062	0.744	2.186	0.615	4.249	0.675
1996	0.719	0.625	1.712	0.281	1.162	0.547	1.269	0.263	2.431	0.334
1997	0.467	0.525	1.201	0.294	0.736	0.464	0.933	0.284	1.669	0.342
1998	0.949	0.458	0.967	0.246	1.119	0.414	0.797	0.253	1.917	0.309
1999	0.160	0.373	0.617	0.334	0.324	0.388	0.453	0.345	0.777	0.327
2000	0.164	0.563	0.725	0.296	0.361	0.385	0.528	0.297	0.889	0.312
2001	0.093	0.645	0.522	0.710	0.169	0.595	0.446	0.744	0.615	0.690
2002	0.000	0.000	0.225	0.473	0.018	1.000	0.207	0.495	0.225	0.473
2003	0.045	0.717	0.229	0.389	0.061	0.589	0.214	0.402	0.274	0.341
2004	0.088	0.590	0.048	0.563	0.120	0.460	0.016	1.000	0.136	0.417
2005	1.981	0.964	0.092	0.712	1.981	0.964	0.092	0.712	2.073	0.921
2006	0.138	0.495	0.056	0.564	0.155	0.503	0.038	0.699	0.194	0.419
2007	0.246	0.717	0.110	0.854	0.302	0.644	0.054	0.745	0.356	0.639
2008	0.234	0.928	0.018	1.000	0.234	0.928	0.018	1.000	0.252	0.862
2009	0.268	0.631	0.249	0.732	0.448	0.697	0.068	0.588	0.516	0.676
2010	0.101	0.841	0.130	0.486	0.167	0.728	0.065	0.482	0.232	0.608
2011	0.000	0.000	0.166	0.792	0.036	0.698	0.129	0.868	0.166	0.792
2012	0.195	1.000	0.272	0.797	0.303	1.000	0.164	0.678	0.467	0.879
2013	0.076	1.000	0.104	0.862	0.112	0.745	0.069	0.804	0.181	0.644
2014	0.091	0.591	0.092	0.710	0.091	0.591	0.092	0.710	0.183	0.566
2015	0.076	0.766	0.234	0.367	0.185	0.525	0.125	0.446	0.309	0.408
2016	0.094	0.517	0.056	0.563	0.131	0.458	0.019	1.000	0.150	0.488
2017	0.068	0.773	0.091	0.503	0.087	0.637	0.072	0.589	0.159	0.456

Table 6: Estimated annual abundance of female PIBKC population components from the NMFS EBS trawl survey.

	immature females		mature females		all females	
	biomass	cv	biomass	cv	biomass	cv
year	1000's t		1000's t		1000's t	
1975	1.270	0.730	11.172	0.691	12.442	0.636
1976	3.178	0.963	2.613	0.807	5.792	0.891
1977	2.313	0.784	11.259	0.896	13.572	0.874
1978	0.321	0.611	6.171	0.738	6.492	0.717
1979	0.108	0.634	1.081	0.805	1.189	0.760
1980	0.728	0.446	211.575	0.986	212.303	0.983
1981	0.687	0.297	5.797	0.496	6.484	0.458
1982	0.613	0.406	8.764	0.694	9.377	0.669
1983	0.384	0.722	9.864	0.784	10.248	0.781
1984	0.054	0.698	3.031	0.382	3.085	0.380
1985	0.005	0.457	0.520	0.448	0.525	0.445
1986	0.011	0.727	2.420	0.901	2.431	0.896
1987	0.128	0.866	0.785	0.590	0.913	0.526
1988	0.240	0.645	0.478	0.490	0.718	0.473
1989	1.032	0.601	0.714	0.470	1.746	0.497
1990	1.314	0.764	1.615	0.454	2.929	0.491
1991	0.659	0.493	2.117	0.397	2.776	0.376
1992	1.106	0.740	1.543	0.463	2.649	0.463
1993	0.455	0.573	1.636	0.457	2.092	0.399
1994	0.320	0.703	4.573	0.454	4.893	0.443
1995	0.386	0.764	3.893	0.518	4.279	0.496
1996	0.166	0.486	5.418	0.504	5.585	0.491
1997	0.189	0.670	2.839	0.429	3.028	0.407
1998	0.420	0.431	1.761	0.460	2.182	0.392
1999	0.113	0.797	2.755	0.459	2.868	0.467
2000	0.023	0.699	1.439	0.462	1.462	0.460
2001	0.000	1.000	1.816	0.722	1.817	0.722
2002	0.000	1.000	1.401	0.776	1.401	0.775
2003	0.021	0.667	1.286	0.745	1.307	0.734
2004	0.005	0.711	0.118	0.516	0.123	0.504
2005	0.477	1.000	0.370	0.570	0.847	0.606
2006	0.038	0.602	0.538	0.760	0.576	0.712
2007	0.045	0.995	0.237	0.826	0.282	0.707
2008	0.178	0.882	0.493	0.659	0.672	0.705
2009	0.030	0.576	0.595	0.840	0.625	0.818
2010	0.083	0.575	0.311	0.660	0.394	0.634
2011	0.015	0.836	0.022	1.000	0.037	0.674
2012	0.131	0.936	0.106	0.436	0.237	0.637
2013	0.035	0.657	0.131	0.816	0.166	0.654
2014	0.016	1.000	0.091	0.605	0.108	0.529
2015	0.020	0.708	0.139	0.687	0.160	0.662
2016	0.073	0.468	0.331	0.496	0.405	0.478
2017	0.108	0.811	0.153	0.558	0.262	0.533

Table 7: Estimated annual abundance of male PIBKC population components from the NMFS EBS trawl survey.

	immature males		mature males		sublegal males		legal males		all males	
	biomass	cv	biomass	cv	biomass	cv	biomass	cv	biomass	cv
year	1000's t		1000's t		1000's t		1000's t		1000's t	
1975	8.341	0.525	38.054	0.501	19.378	0.466	27.016	0.499	46.395	0.475
1976	4.129	0.944	14.059	0.451	5.539	0.811	12.649	0.468	18.188	0.452
1977	3.713	0.443	42.618	0.768	5.966	0.463	40.366	0.784	46.332	0.729
1978	2.765	0.509	17.370	0.558	6.618	0.412	13.517	0.642	20.135	0.506
1979	0.061	0.785	10.959	0.315	1.981	0.452	9.040	0.311	11.021	0.315
1980	2.084	0.492	23.553	0.430	4.958	0.464	20.679	0.446	25.637	0.417
1981	1.704	0.299	11.628	0.174	2.779	0.297	10.554	0.175	13.332	0.175
1982	1.152	0.232	7.389	0.187	1.647	0.217	6.893	0.192	8.541	0.175
1983	0.962	0.357	5.409	0.178	1.897	0.297	4.474	0.175	6.371	0.187
1984	0.130	0.362	2.216	0.229	0.521	0.268	1.824	0.247	2.345	0.222
1985	0.039	0.733	1.055	0.267	0.338	0.374	0.755	0.283	1.094	0.263
1986	0.004	1.000	1.505	0.303	0.035	0.897	1.473	0.307	1.508	0.302
1987	0.191	0.783	2.923	0.411	0.334	0.536	2.781	0.414	3.115	0.397
1988	0.170	0.707	0.842	0.529	0.170	0.707	0.842	0.529	1.012	0.457
1989	1.275	0.620	0.827	0.637	1.275	0.620	0.827	0.637	2.102	0.551
1990	2.004	0.661	3.078	0.600	3.567	0.665	1.514	0.515	5.082	0.610
1991	1.377	0.386	4.690	0.386	2.741	0.336	3.326	0.450	6.067	0.373
1992	1.801	0.512	4.391	0.423	3.157	0.446	3.035	0.446	6.192	0.432
1993	1.088	0.545	4.556	0.307	2.442	0.409	3.203	0.301	5.644	0.305
1994	0.619	0.388	3.410	0.345	1.224	0.350	2.806	0.351	4.029	0.343
1995	0.968	0.863	8.360	0.604	2.541	0.673	6.787	0.615	9.328	0.629
1996	0.745	0.605	4.641	0.269	1.512	0.524	3.873	0.265	5.386	0.279
1997	0.381	0.545	3.233	0.276	0.849	0.451	2.765	0.271	3.614	0.294
1998	0.692	0.413	2.798	0.249	0.980	0.354	2.510	0.255	3.490	0.252
1999	0.161	0.402	1.729	0.337	0.464	0.414	1.426	0.347	1.890	0.333
2000	0.113	0.679	2.091	0.296	0.459	0.373	1.746	0.305	2.205	0.304
2001	0.087	0.764	1.599	0.735	0.225	0.628	1.461	0.759	1.686	0.733
2002	0.000	0.000	0.680	0.506	0.033	1.000	0.647	0.525	0.680	0.506
2003	0.019	0.984	0.702	0.400	0.050	0.723	0.671	0.411	0.721	0.390
2004	0.036	0.649	0.107	0.583	0.094	0.487	0.048	1.000	0.143	0.455
2005	0.326	0.942	0.344	0.710	0.326	0.942	0.344	0.710	0.670	0.589
2006	0.087	0.585	0.166	0.603	0.114	0.616	0.139	0.699	0.253	0.462
2007	0.197	0.737	0.306	0.798	0.298	0.632	0.206	0.734	0.503	0.661
2008	0.212	0.952	0.046	1.000	0.212	0.952	0.046	1.000	0.258	0.797
2009	0.254	0.680	0.497	0.713	0.565	0.740	0.187	0.604	0.751	0.698
2010	0.092	0.853	0.303	0.461	0.205	0.702	0.190	0.483	0.395	0.522
2011	0.000	0.000	0.461	0.843	0.062	0.705	0.399	0.886	0.461	0.843
2012	0.165	1.000	0.644	0.735	0.350	1.000	0.459	0.643	0.809	0.786
2013	0.015	1.000	0.250	0.797	0.075	0.824	0.190	0.752	0.265	0.754
2014	0.083	0.623	0.233	0.699	0.083	0.623	0.233	0.699	0.317	0.567
2015	0.082	0.747	0.622	0.394	0.275	0.494	0.428	0.458	0.703	0.395
2016	0.071	0.486	0.130	0.613	0.133	0.495	0.068	1.000	0.201	0.515
2017	0.046	0.767	0.255	0.514	0.076	0.599	0.224	0.573	0.300	0.470

Size compositions

Annual size compositions for PIBKC in the NMFS EBS trawl survey were calculated by sex, shell condition, and 5mm size (carapace width) bin, accumulating individuals > 200 mm CL in the last size bin (195-200 mm CL). There is no need here to distinguish among the population components used above to present abundance and biomass trends (e.g., immature females) in the following size compositions because those components were based on size ranges that can be extracted from the size compositions.

By sex

Size compositions for PIBKC from the NMFS EBS trawl survey are presented here by sex for the entire survey time period (1975-present) and for 2001-present.

By sex and shell condition

Size compositions for PIBKC from the NMFS EBS trawl survey are presented here by sex for the entire survey time period (1975-present) and for 2001-present.

Spatial patterns

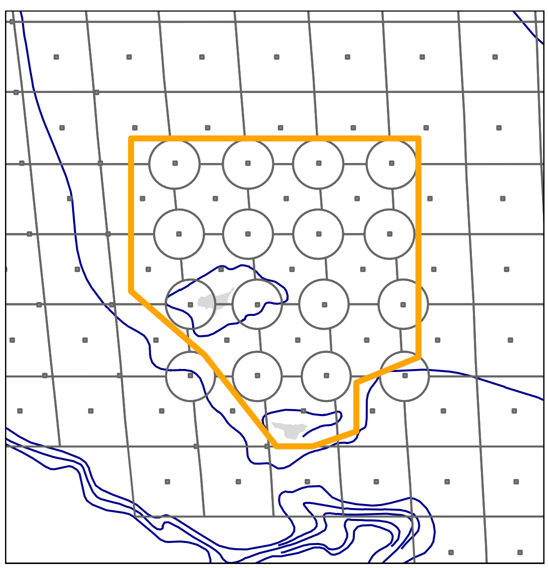

Figure 10: Basemap for future maps, with EBS bathymetry (blue lines), NMFS EBS trawl survey station grid (black) lines, and the Pribilof Islands Habitat Conservation Area (orange outline).

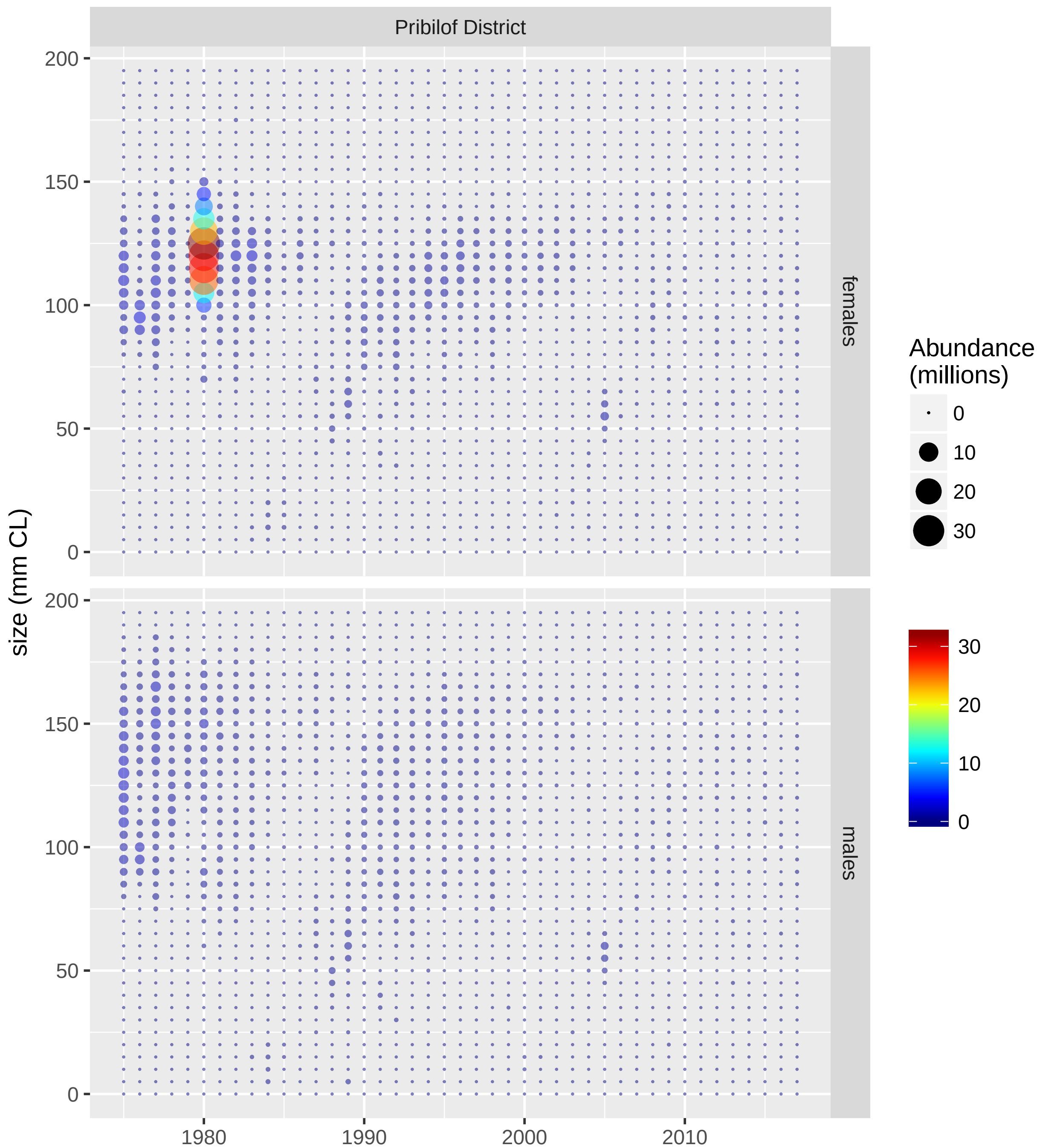

Figure 6: Annual size compositions for PIBKC in the NMFS EBS trawl survey, by sex, over the entire survey period.

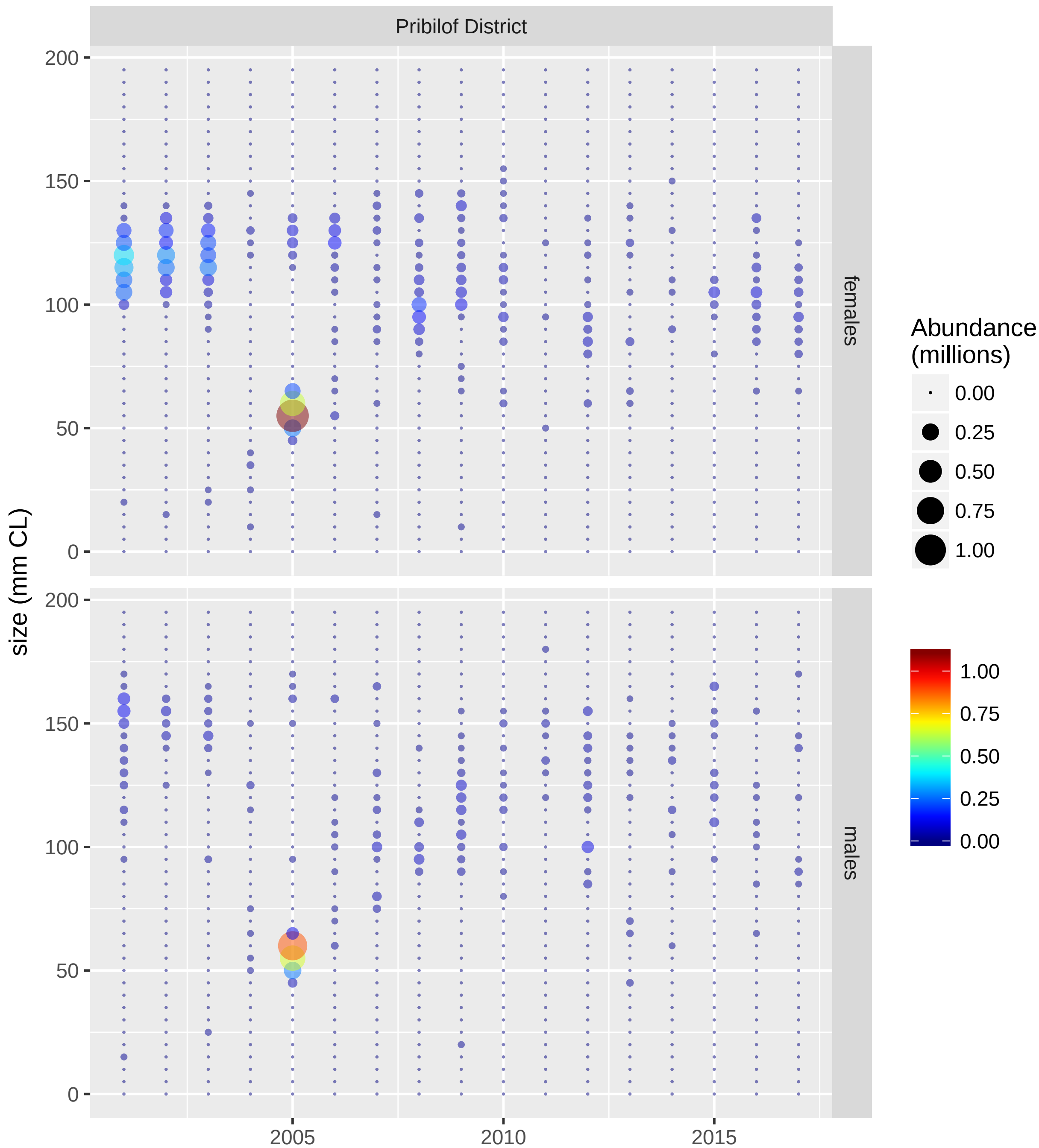

Figure 7: Annual size compositions for PIBKC in the NMFS EBS trawl survey, by sex, since 2001.

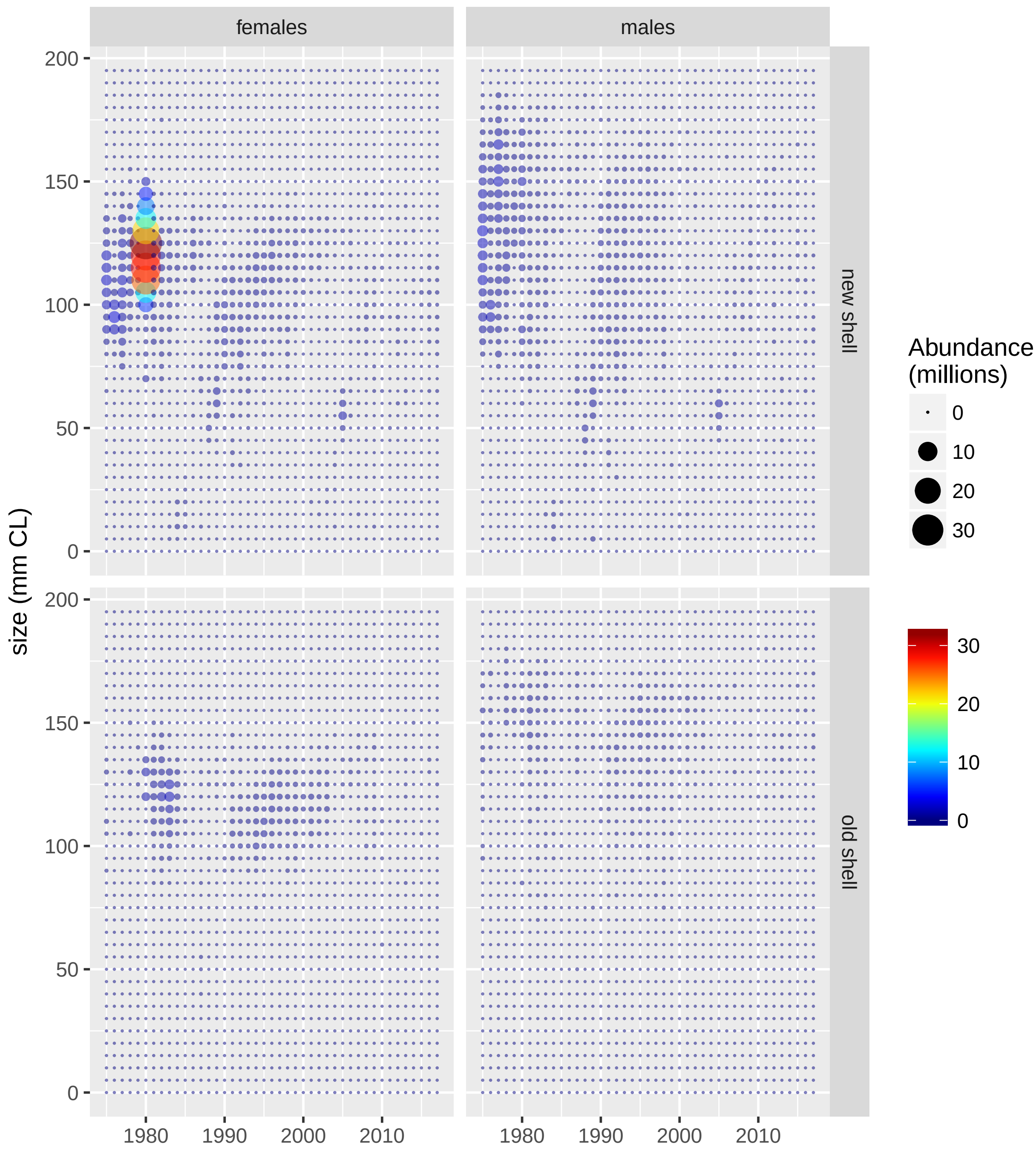

Figure 8: Annual size compositions for PIBKC in the NMFS EBS trawl survey, by sex and shell condition, for entire survey period.

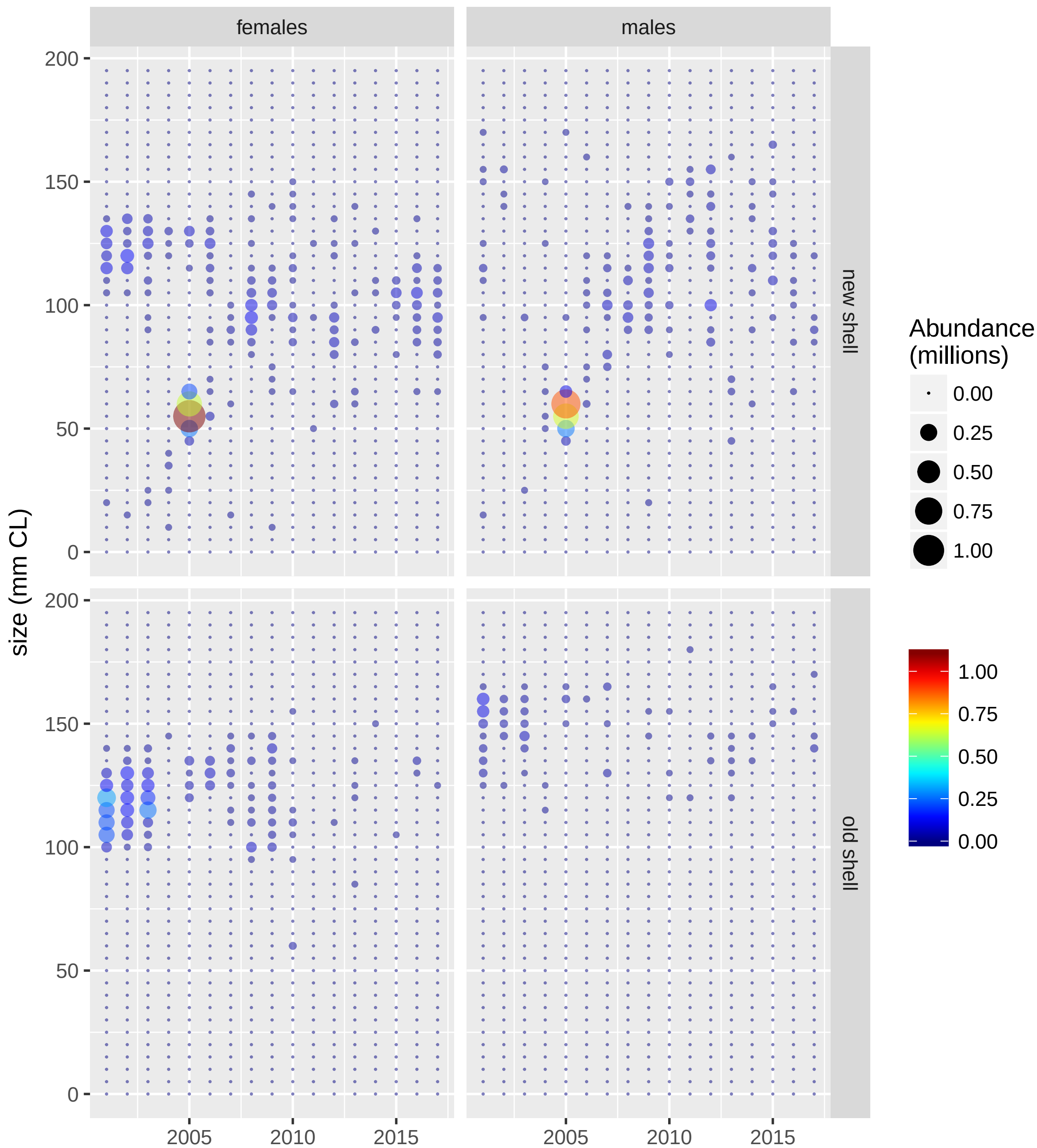

Figure 9: Annual size compositions for PIBKC in the NMFS EBS trawl survey, by sex and shell condition, since 2000.

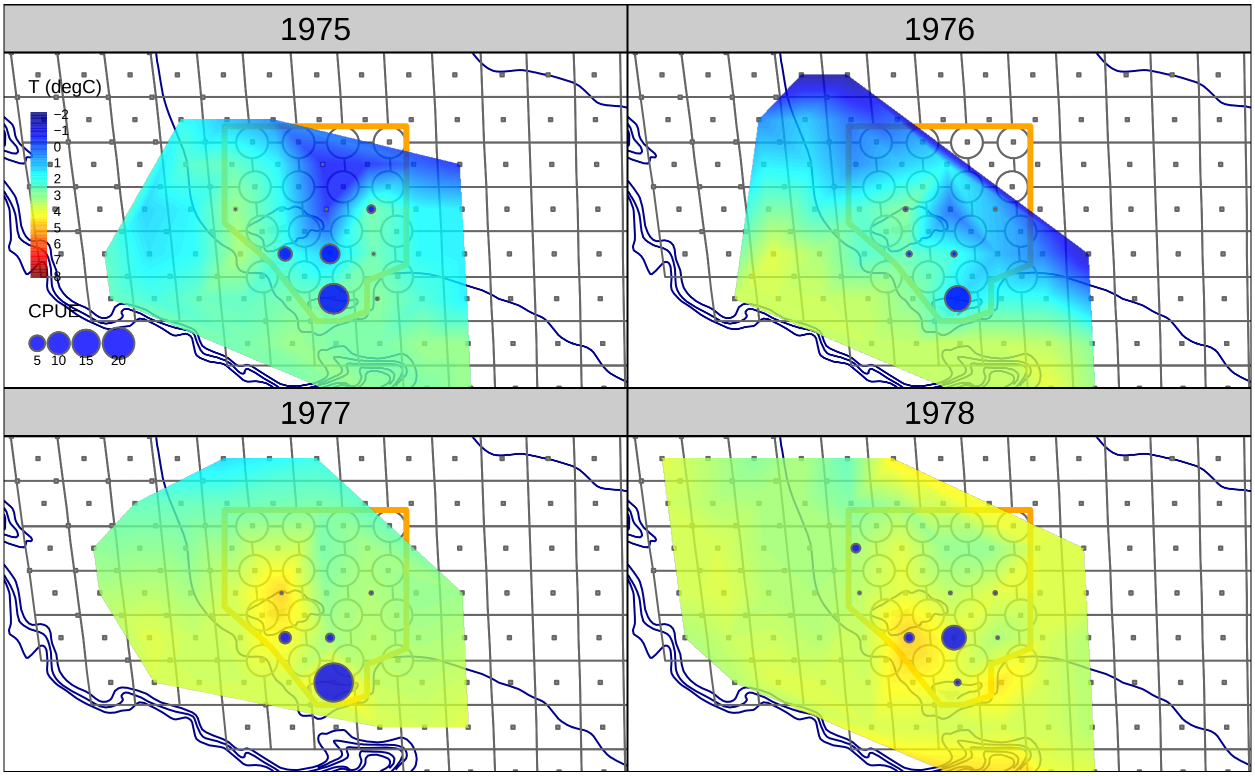

Figure 11: Survey CPUE (biomass) for females PIBKC. Page 1 of 11

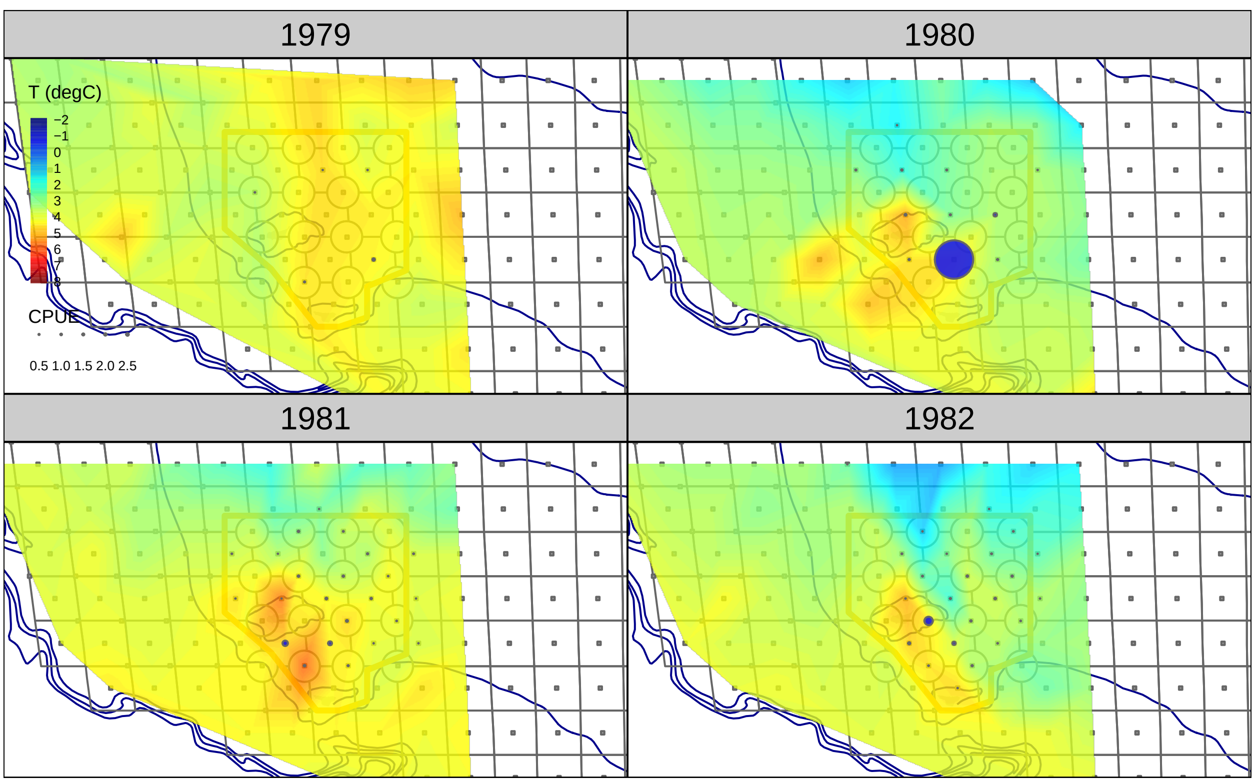

Figure 12: Survey CPUE (biomass) for females PIBKC. Page 2 of 11

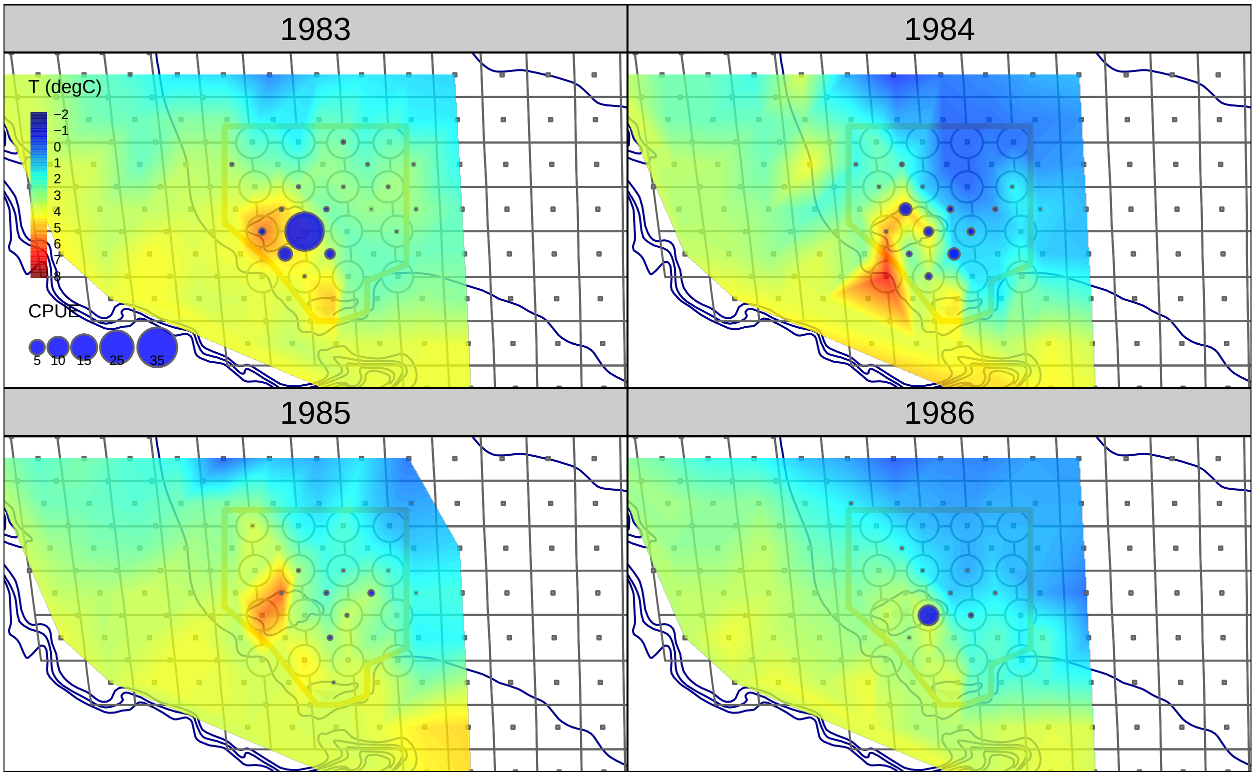

Figure 13: Survey CPUE (biomass) for females PIBKC. Page 3 of 11

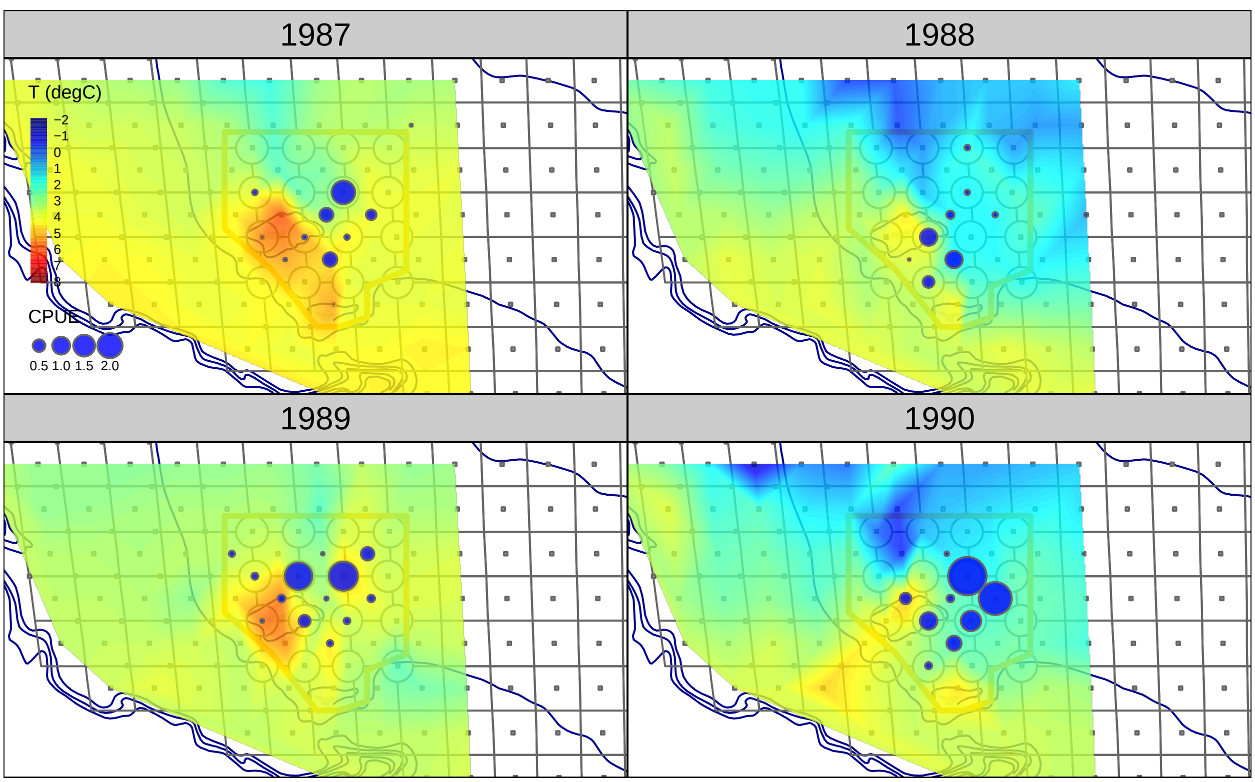

Figure 14: Survey CPUE (biomass) for females PIBKC. Page 4 of 11

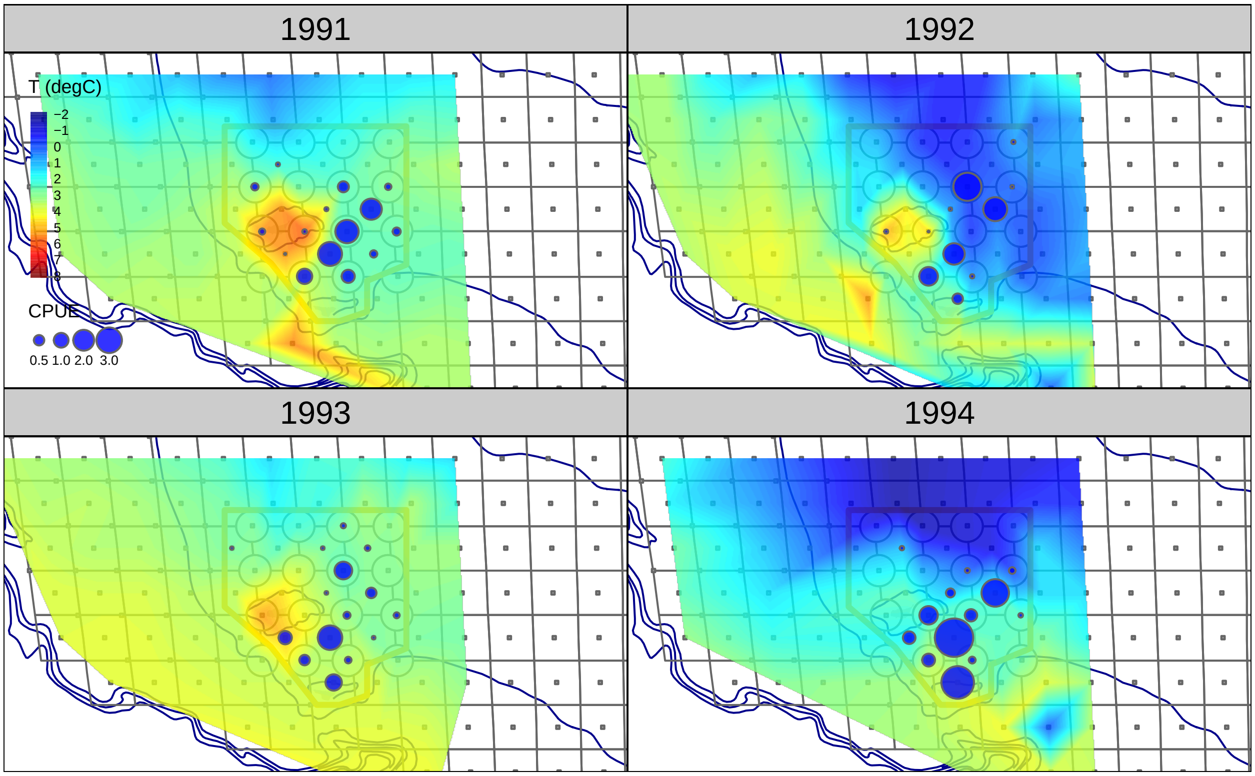

Figure 15: Survey CPUE (biomass) for females PIBKC. Page 5 of 11

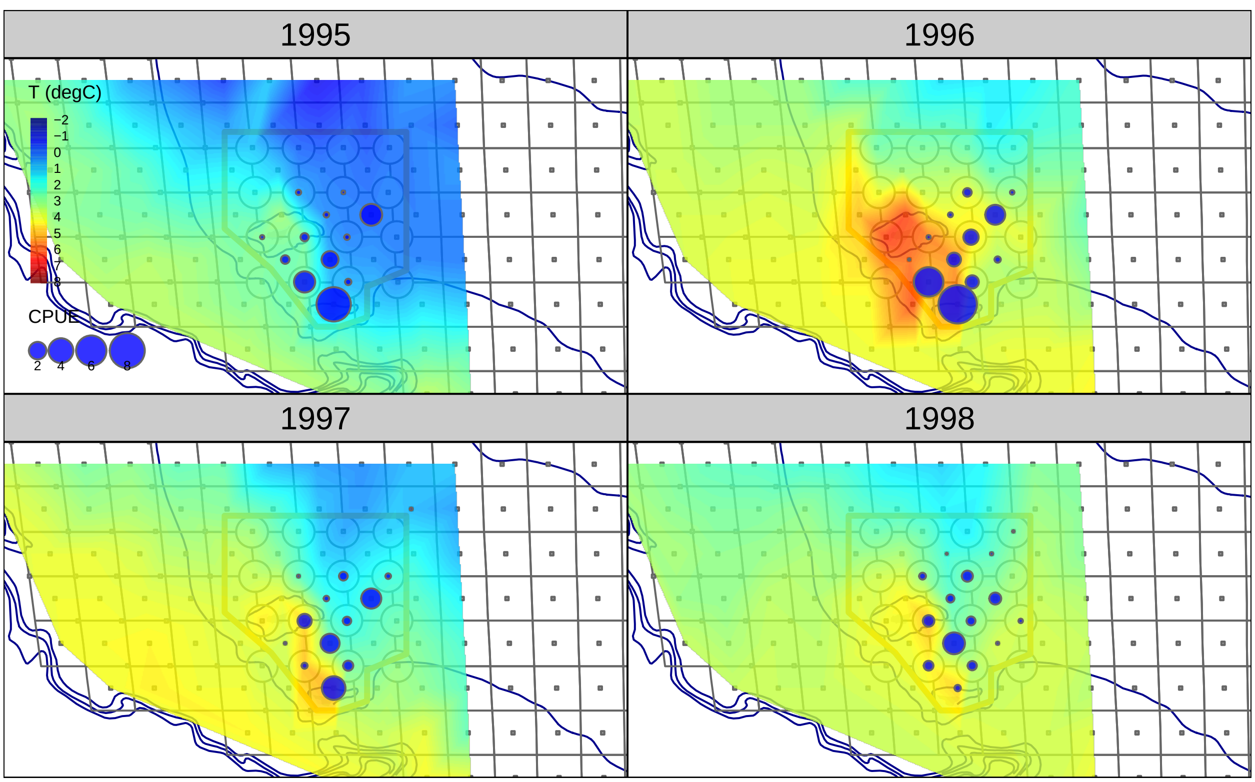

Figure 16: Survey CPUE (biomass) for females PIBKC. Page 6 of 11

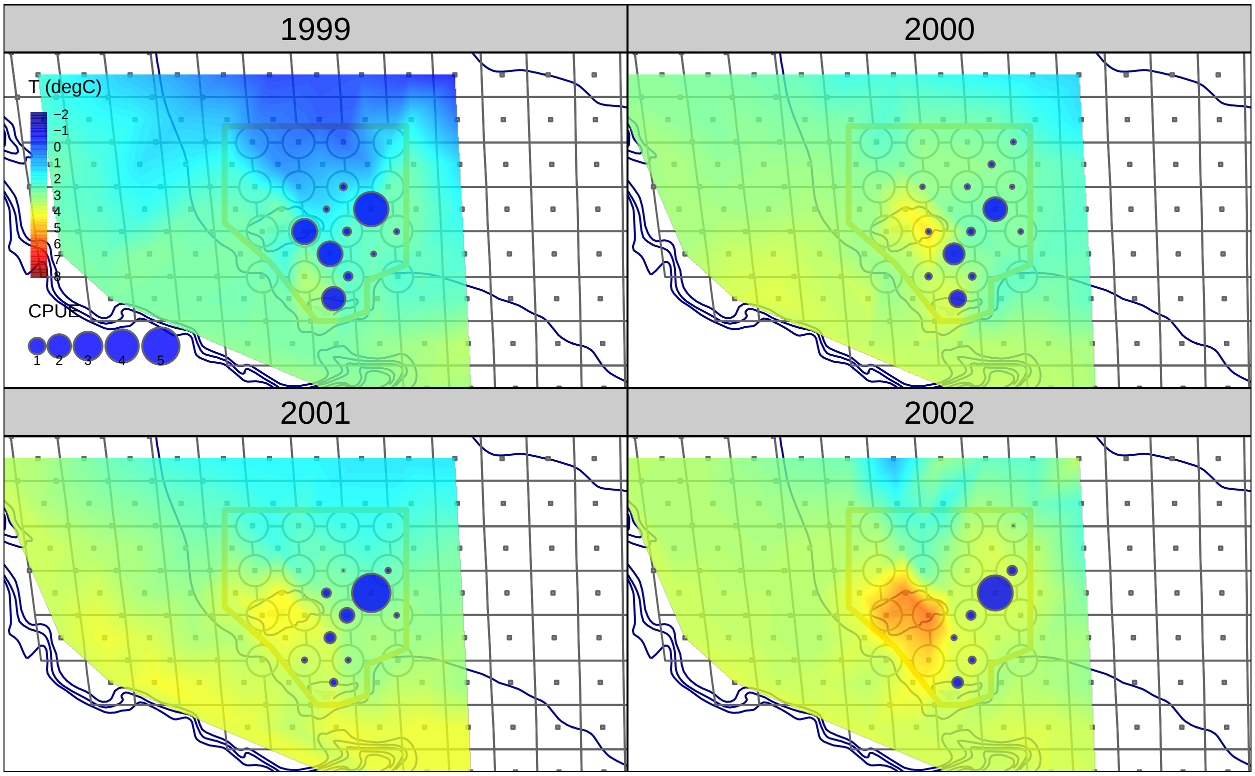

Figure 17: Survey CPUE (biomass) for females PIBKC. Page 7 of 11

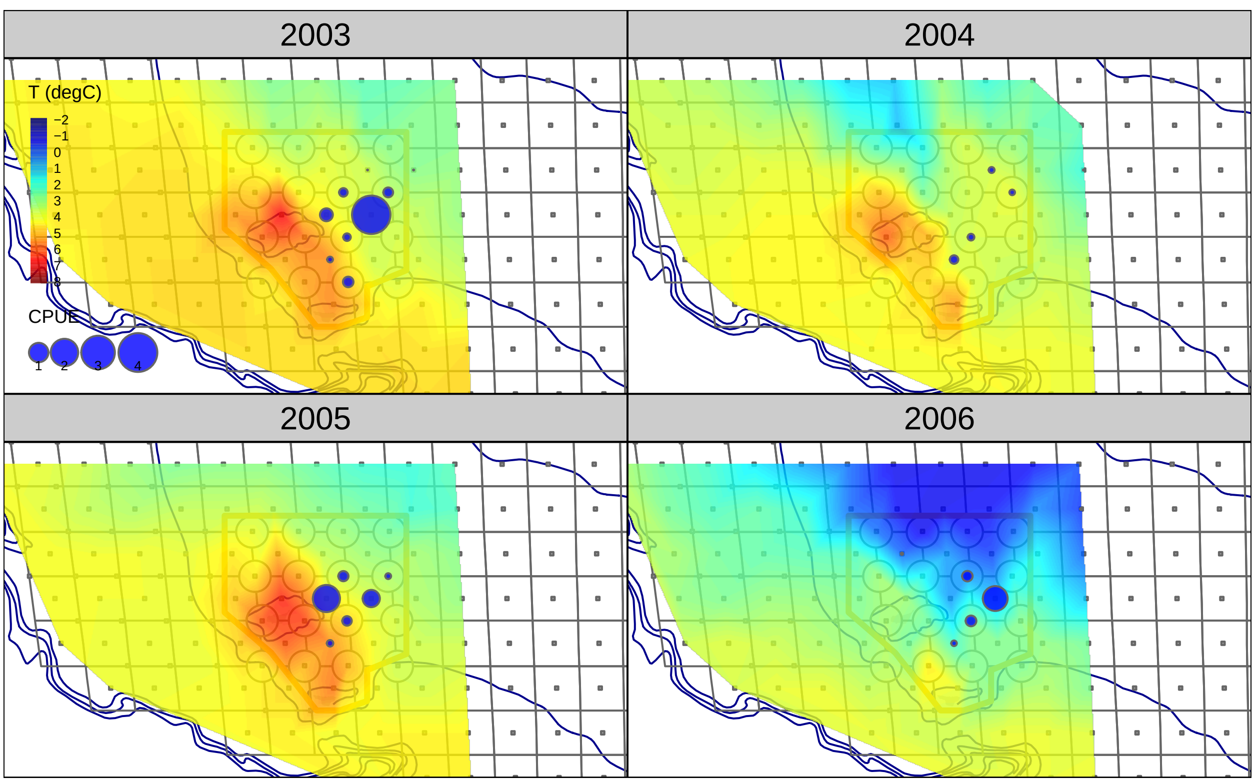

Figure 18: Survey CPUE (biomass) for females PIBKC. Page 8 of 11

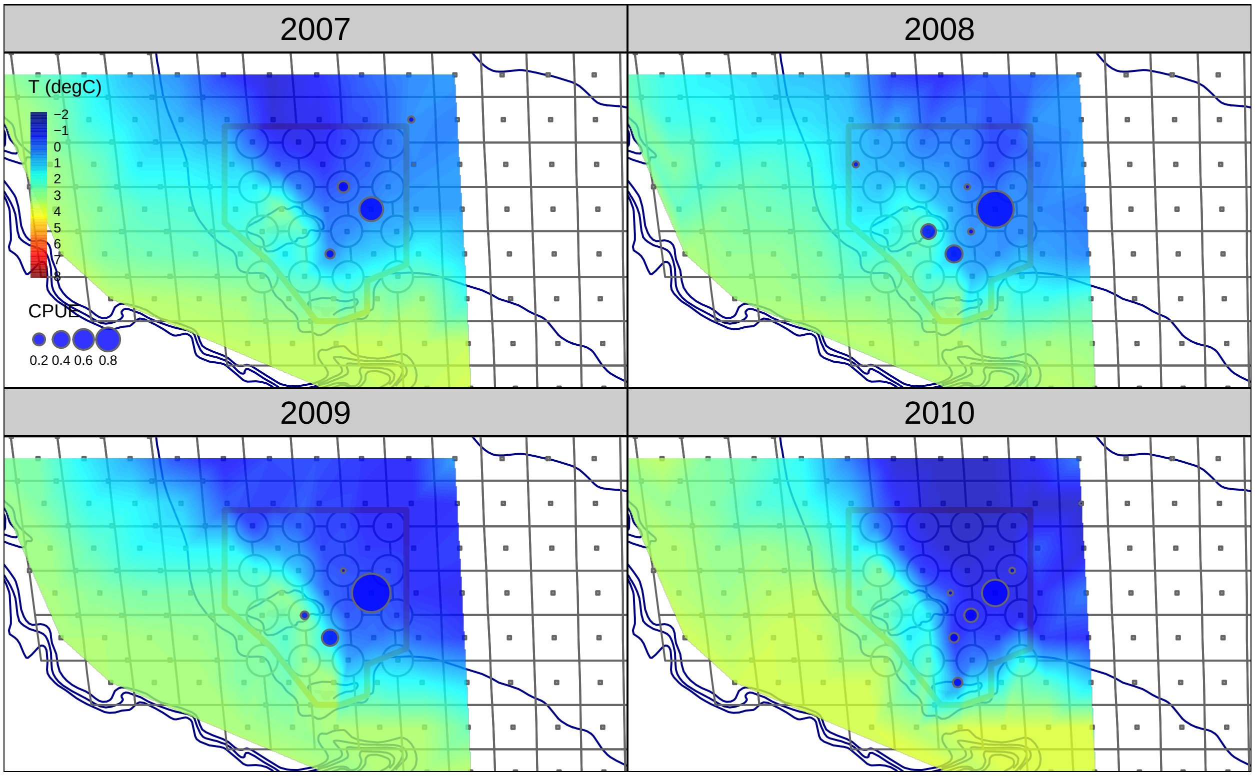

Figure 19: Survey CPUE (biomass) for females PIBKC. Page 9 of 11

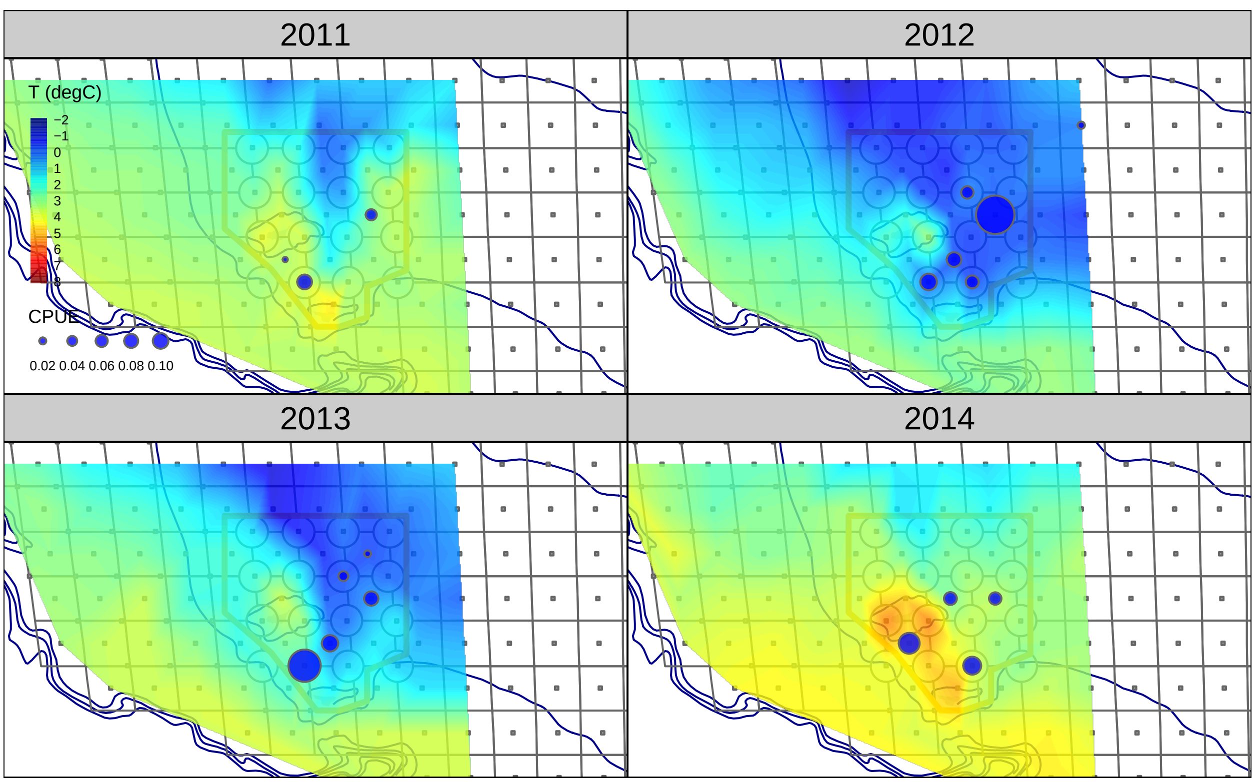

Figure 20: Survey CPUE (biomass) for females PIBKC. Page 10 of 11

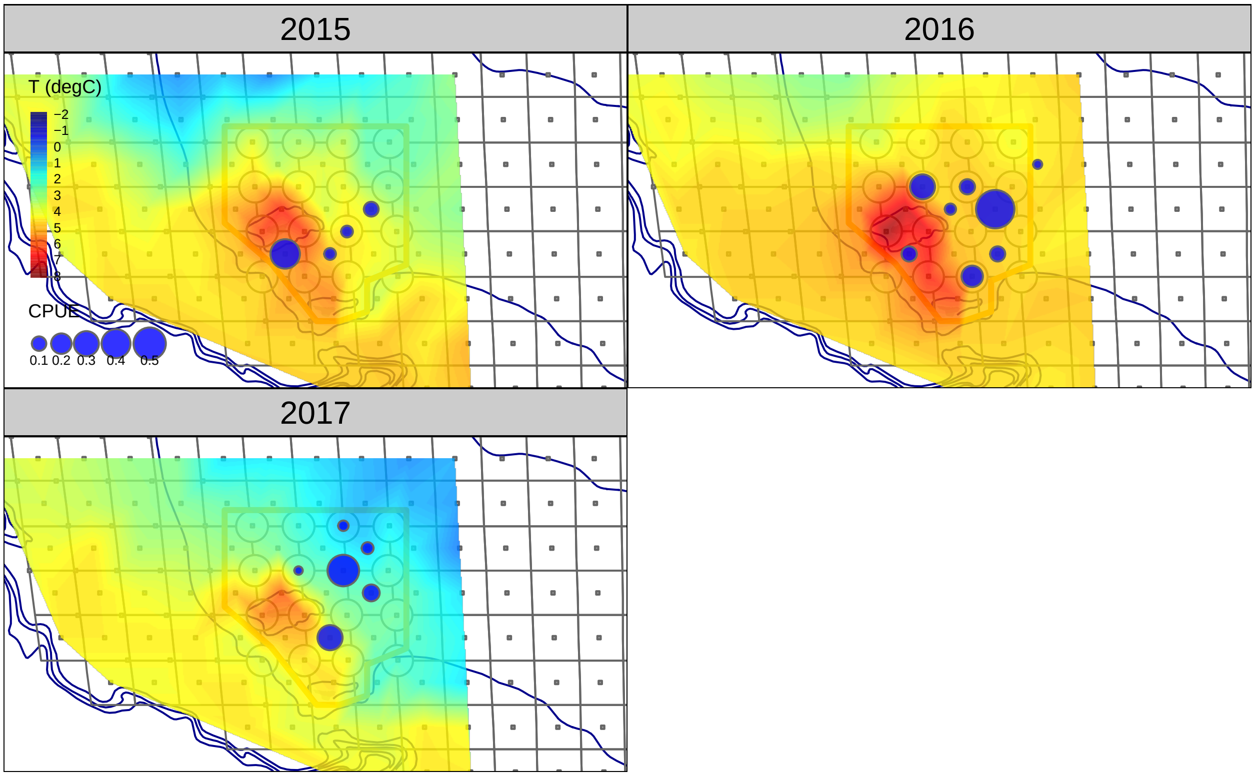

Figure 21: Survey CPUE (biomass) for females PIBKC. Page 11 of 11

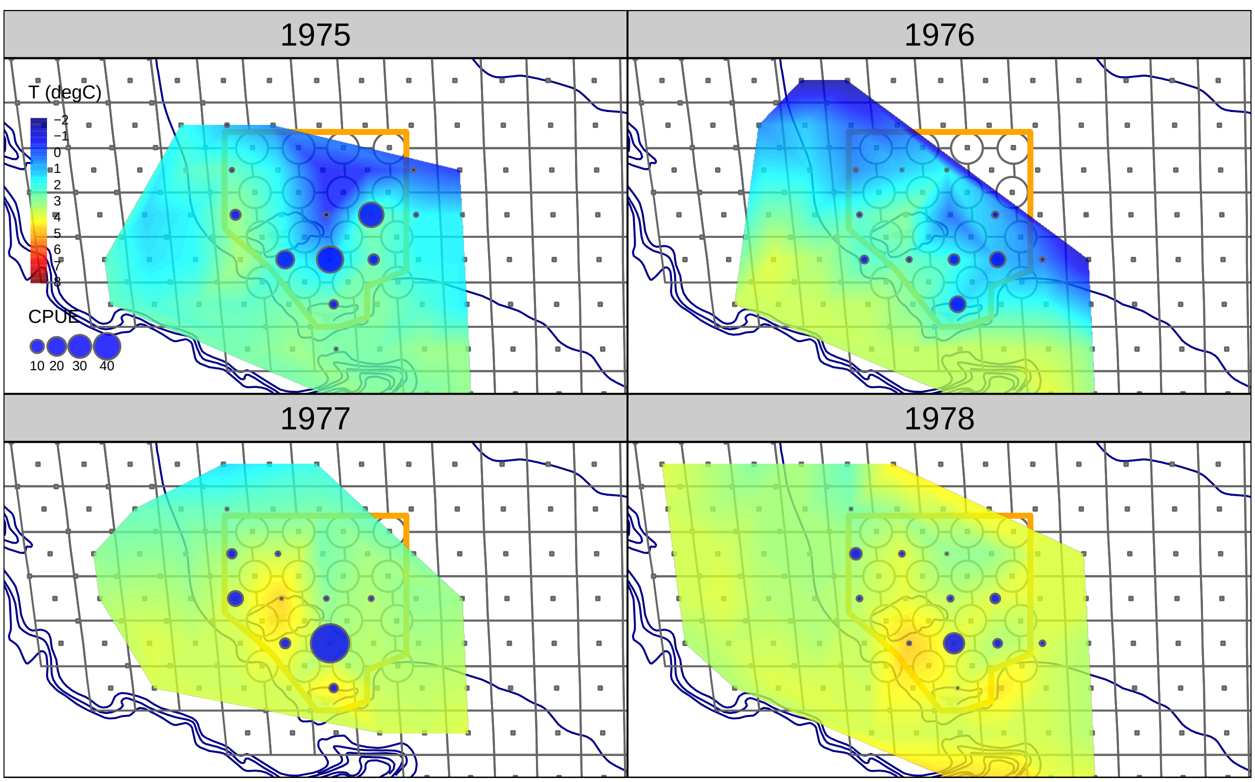

Figure 22: Survey CPUE (biomass) for males PIBKC. Page 1 of 11

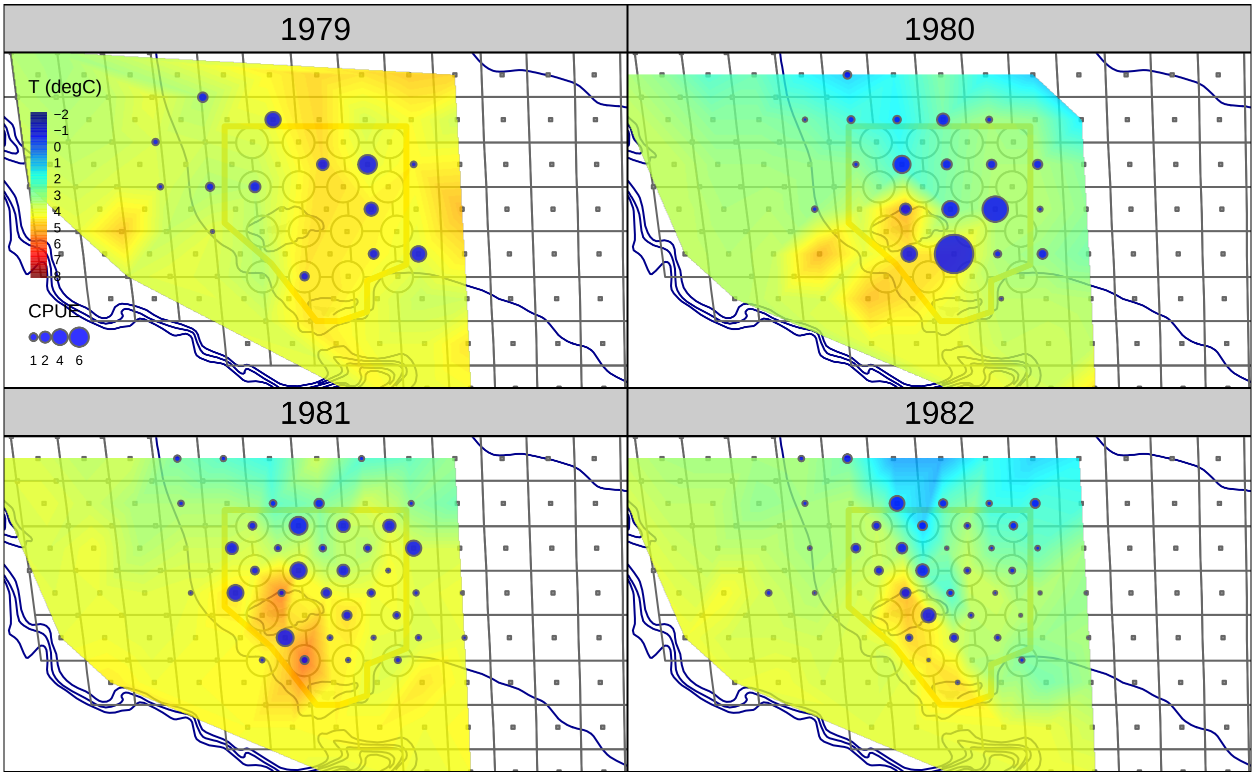

Figure 23: Survey CPUE (biomass) for males PIBKC. Page 2 of 11

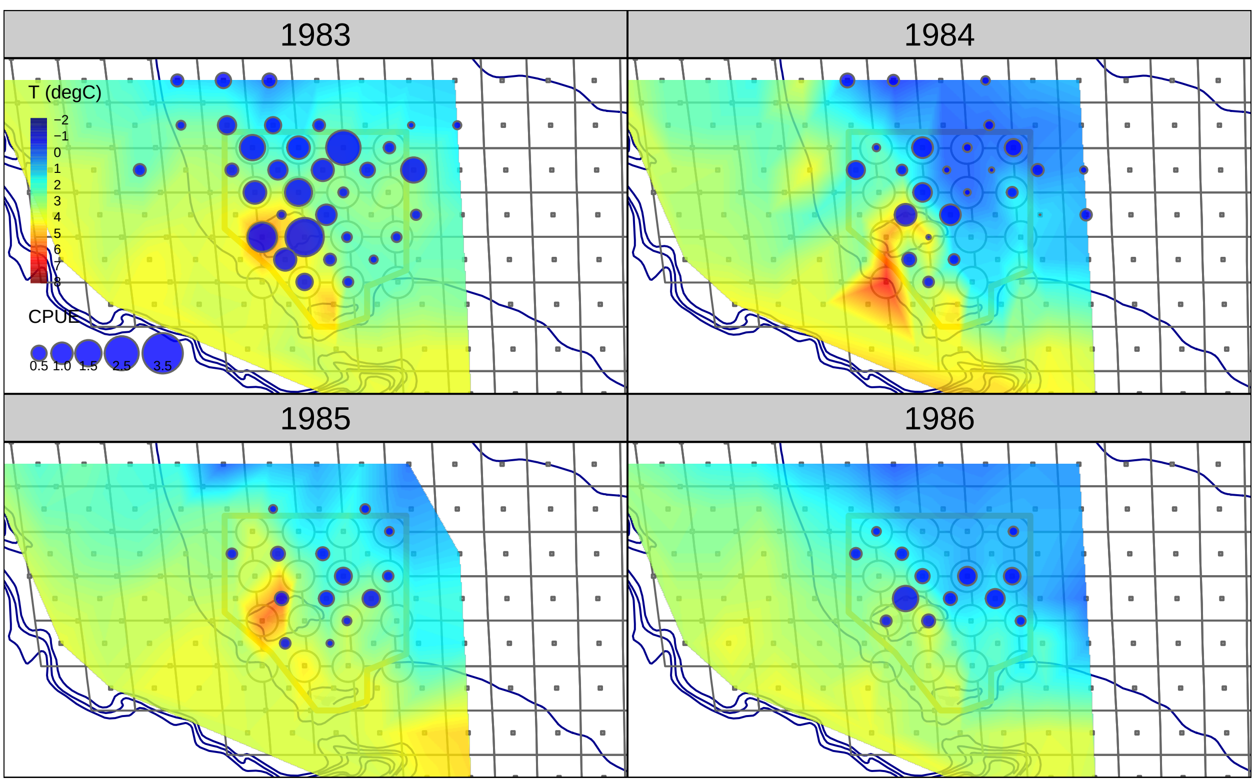

Figure 24: Survey CPUE (biomass) for males PIBKC. Page 3 of 11

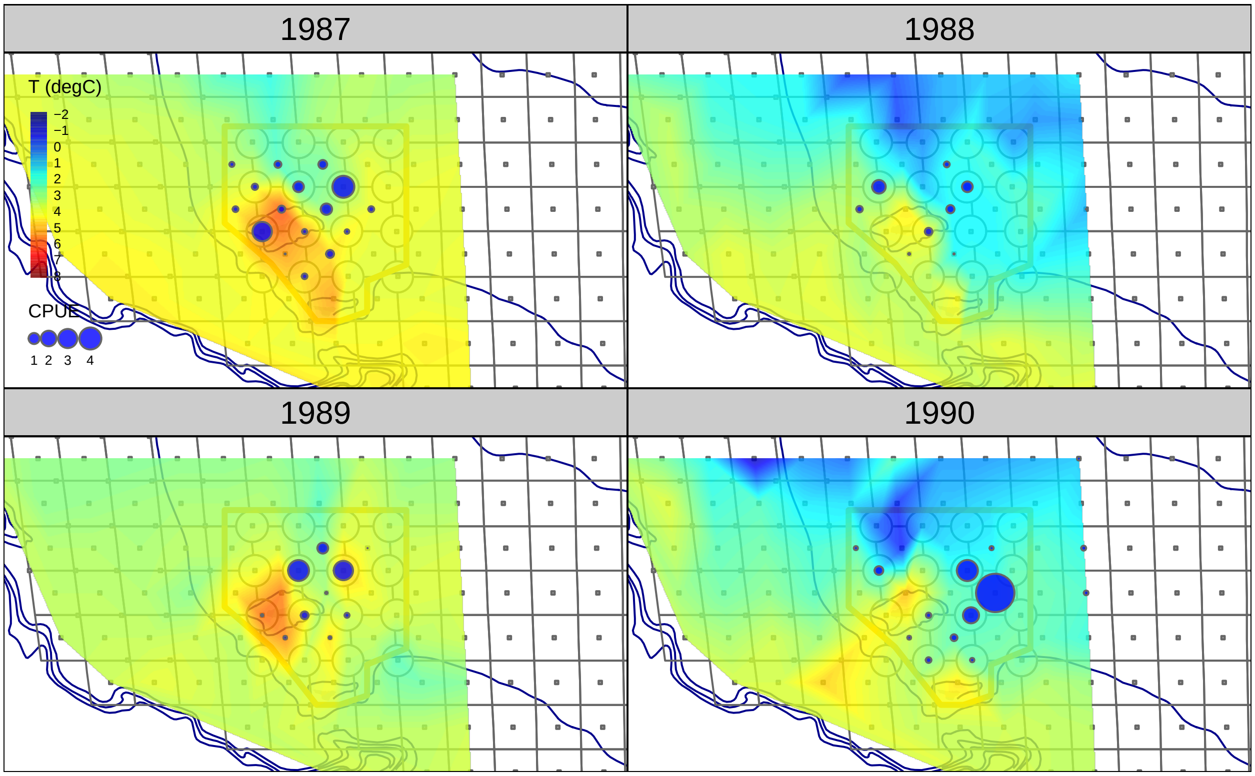

Figure 25: Survey CPUE (biomass) for males PIBKC. Page 4 of 11

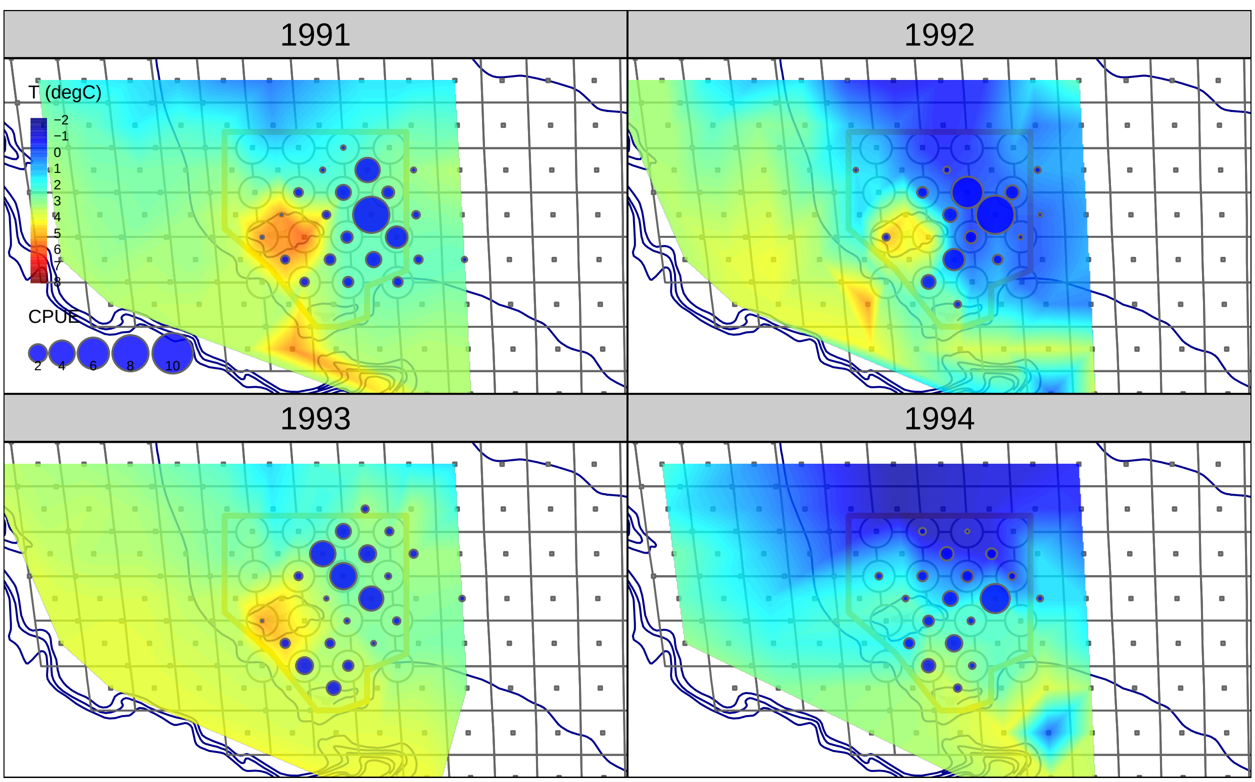

Figure 26: Survey CPUE (biomass) for males PIBKC. Page 5 of 11

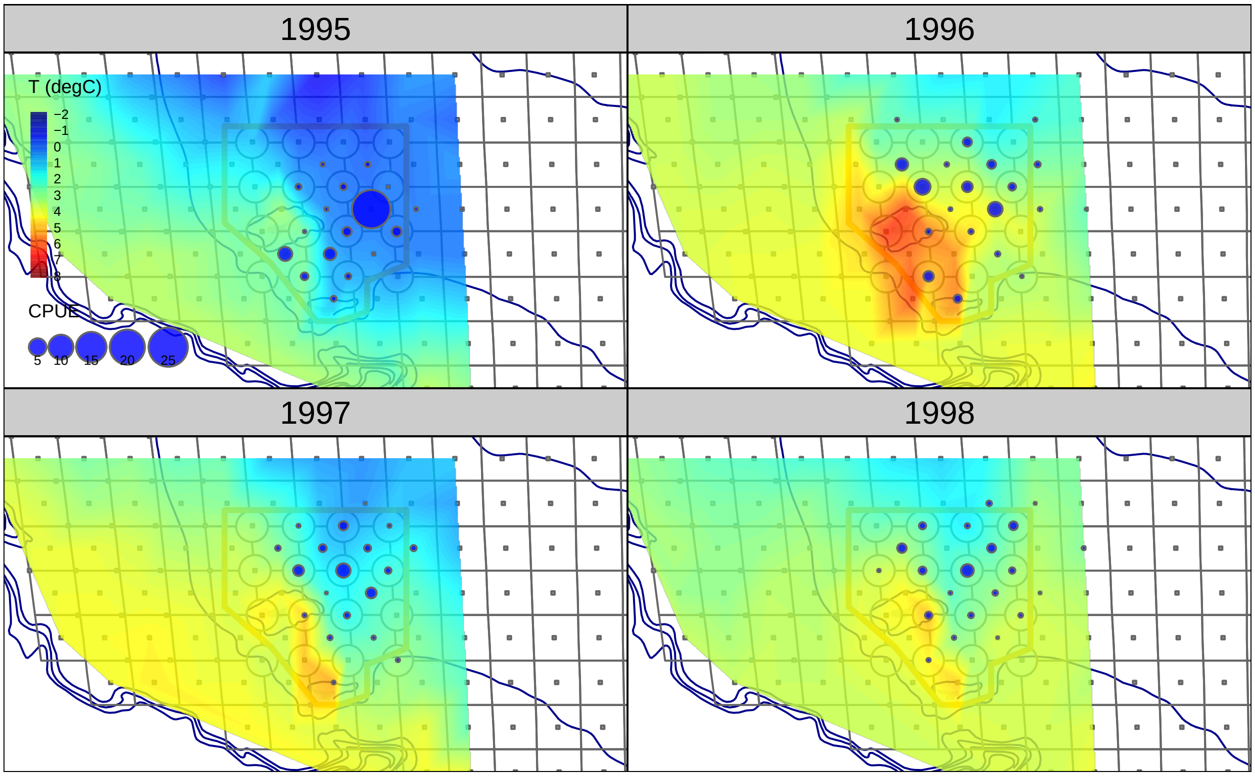

Figure 27: Survey CPUE (biomass) for males PIBKC. Page 6 of 11

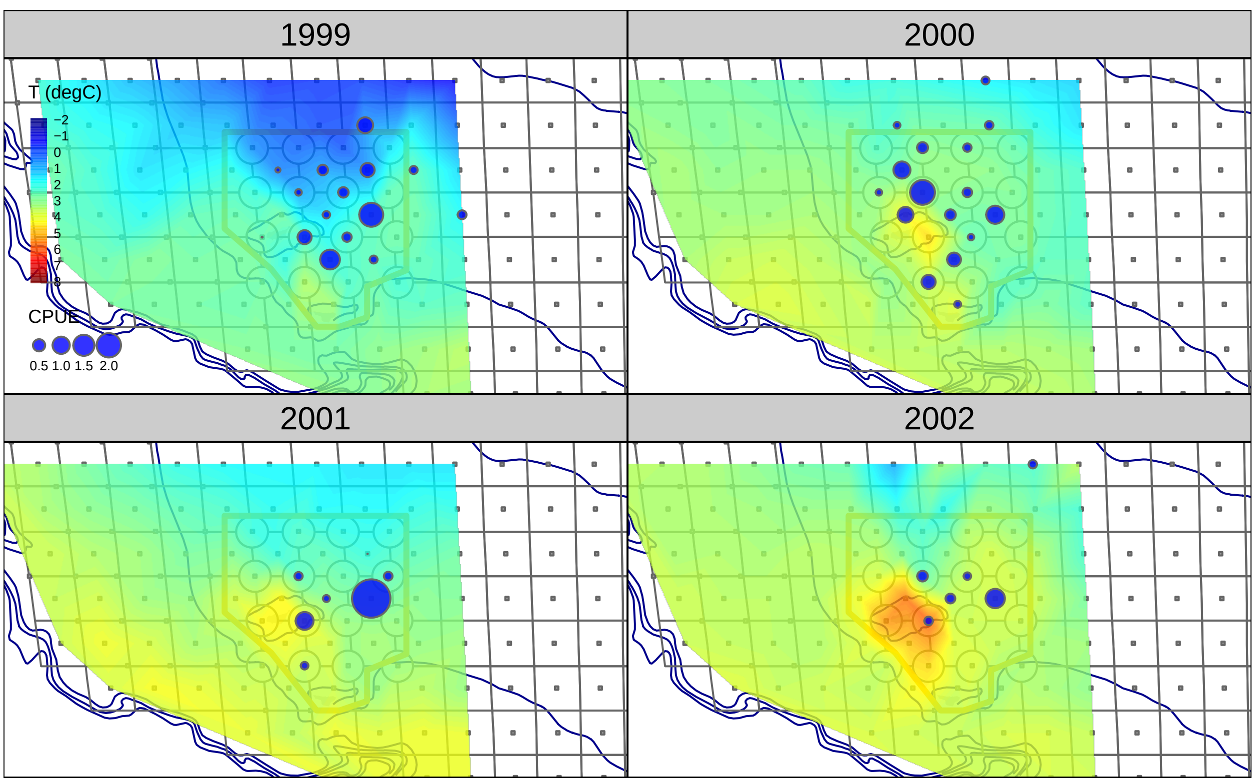

Figure 28: Survey CPUE (biomass) for males PIBKC. Page 7 of 11

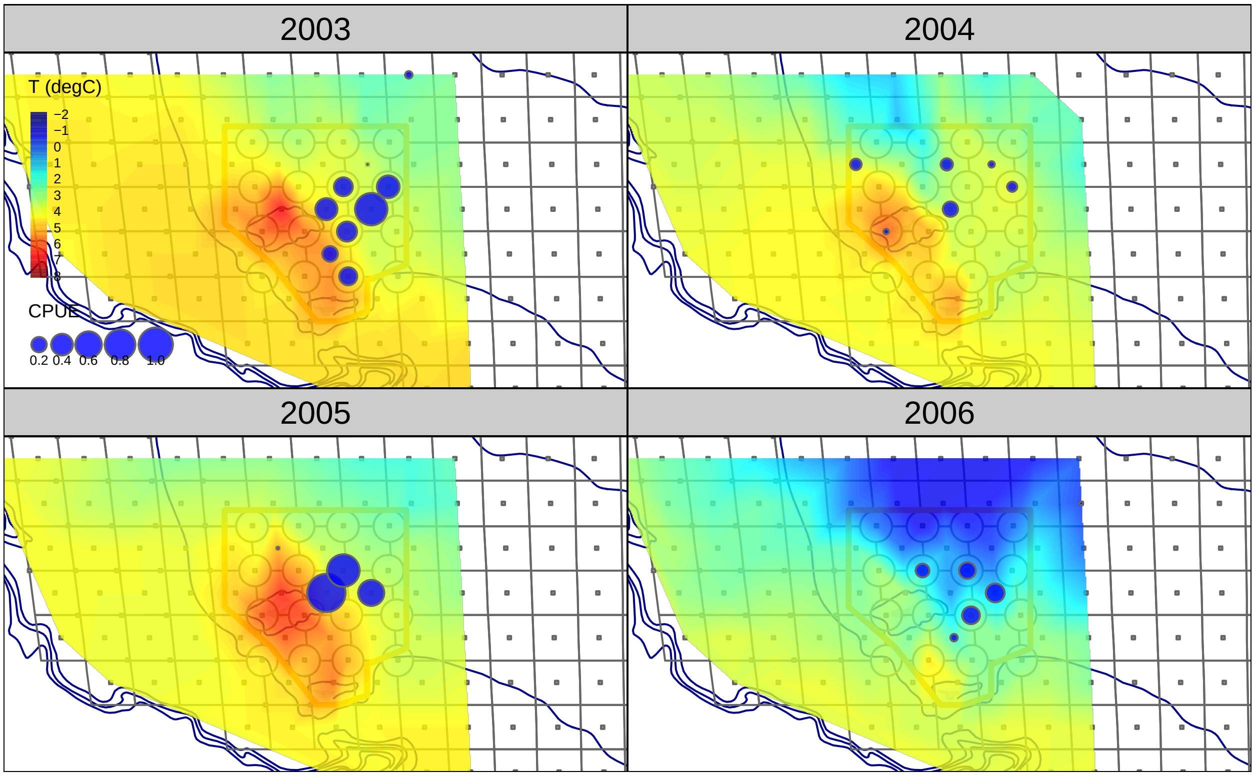

Figure 29: Survey CPUE (biomass) for males PIBKC. Page 8 of 11

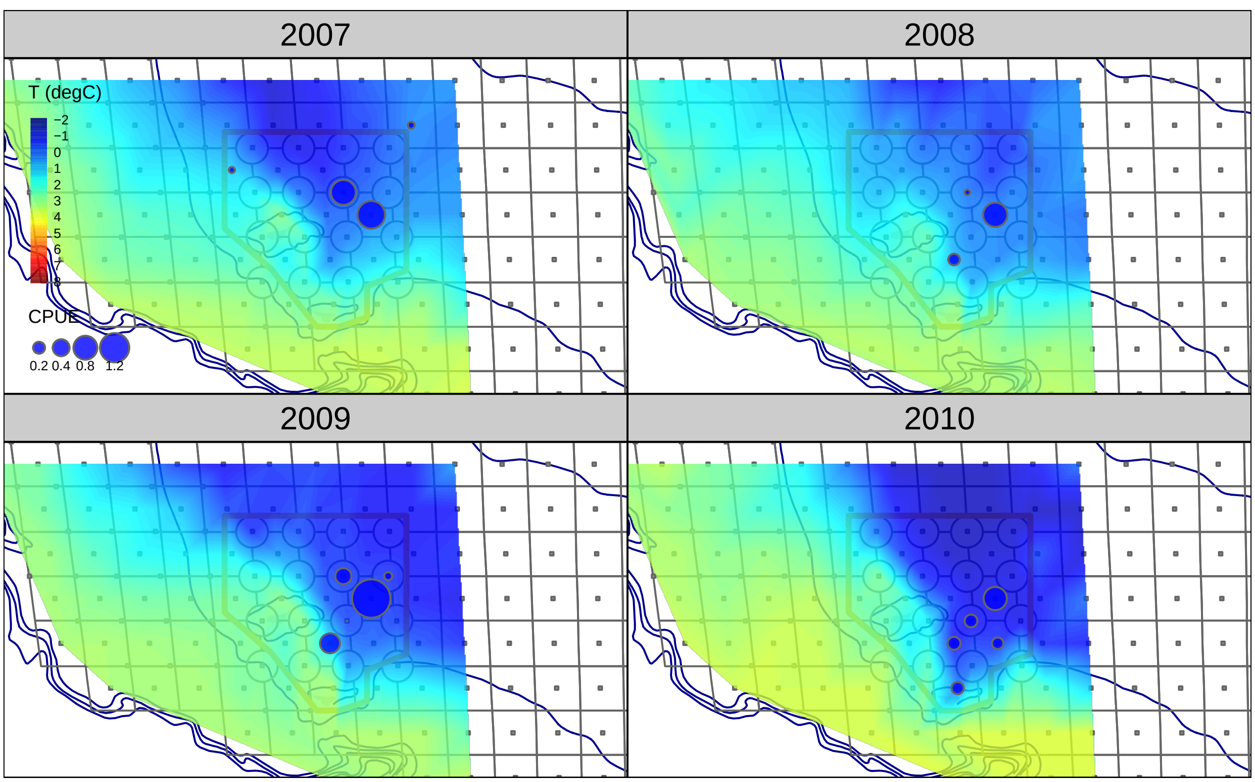

Figure 30: Survey CPUE (biomass) for males PIBKC. Page 9 of 11

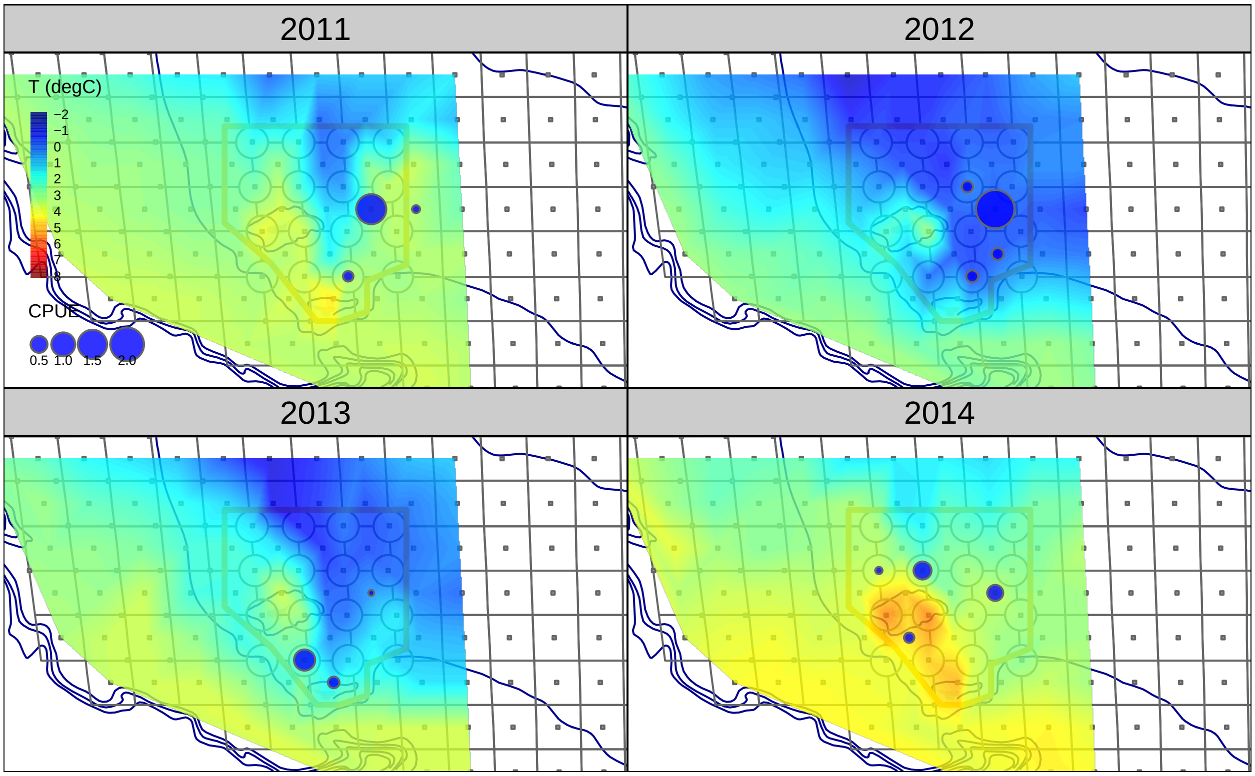

Figure 31: Survey CPUE (biomass) for males PIBKC. Page 10 of 11

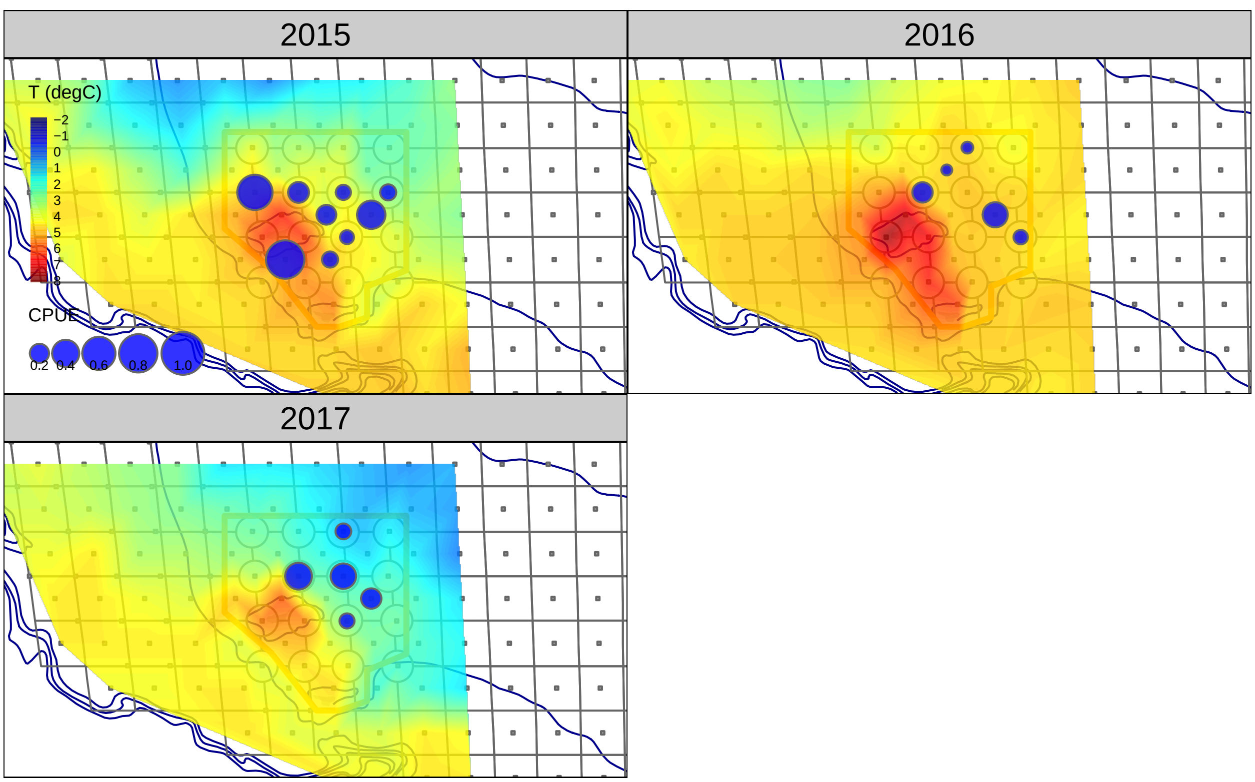

Figure 32: Survey CPUE (biomass) for males PIBKC. Page 11 of 11

Appendix C: PIBKC 2017 Status Determination

William T. Stockhausen

11 September, 2017

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Introduction

This is an appendix to the 2017 stock assessment chapter for the Pribilof Islands blue king crab stock (PIBKC). It presents results for status determination (is overfishing occurring?, is the stock overfished?) for the current year using the "rPIBKC"" R package developed by the assessment author. The rPIBKC package (source code and R package) is available under version control at https://github.com/wStockhausen/rPIBKC.git.

Status Determination and OFL calculations

For all crab stocks managed by the NPFMC, overfishing is evaluated by comparing the previous year's catch mortality (retained + discard mortality) to the previous year's OFL: if the former is greater than the latter, then overfishing is occurring. Overfished status is assessed with respect to MSST, the Minimum Stock Size Threshold. If stock biomass drops below the MSST, the stock is considered to be overfished. For crab stocks, MSST is one-half B_{MSY}, where B_{MSY} is the longterm spawning stock biomass when the stock is fished at maximum sustainable yield (MSY). Thus, the stock is overfished if $B/B_{MSY} < 0.5$, where B is the "current"" spawning stock biomass. In general, the overfishing limit (OFL) for the subsequent year is based on B/B_{MSY} and an "F_{OFL}" harvest control rule, where F_{OFL} is the fishing mortality rate that yields the OFL. Furthermore, if $B/B_{MSY} < \beta(= 0.25)$, directed fishing on the stock is prohibited. For PIBKC, the OFL is based on average historic catch mortality over a specified time period (a Tier 5 approach) and is consequently fixed at 1.16 t.

PIBKC falls into Tier 4 for status determination. For Tier 4 stocks, it is not possible to determine B_{MSY} and MSST directly. Instead, average mature male biomass (MMB) at the time of mating

(“MMB at mating”“) is used as a proxy for B_{MSY}, where the averaging is over some time period assumed to be representative of the stock being fished at an average rate near F_{MSY} and is thus fluctuating around B_{MSY}. For PIBKC, the NPFMC’s Science and Statistical Committee (SSC) has endorsed using the disjoint time periods [1980-84, 1990-97] to calculate $B_{MSY_{proxy}}$ to avoid time periods of low abundance possibly caused by high fishing pressure. Alternative time periods (e.g., 1975 to 1979) have also been considered but rejected. Once $B_{MSY_{proxy}}$ has been calculated, overfished status is then determined by the ratio $B/B_{MSY_{proxy}}$: the stock is overfished if the ratio is less than 0.5, where B is taken as”current" MMB-at-mating.

MMB-at-mating

MMB-at-mating (MMB_m) is calculated from MMB at the time of the annual NMFS EBS bottom trawl survey (MMB_s) by accounting for natural and fishing mortality from the time of the survey to mating. MMB at the time of the survey in year y is calculated from survey data using:

$$MMB_{s_y} = \sum_z w_z \cdot P_z \cdot n_{z,y}$$

where w_z is male weight at size z (mm CL), P_z is the probability of maturity at size z, and $n_{z,y}$ is survey-estimated male abundance at size z in year y.

For a year y prior to the assessment year, MMB_{m_y} is given by

1. $MMB_{f_y} = MMB_{s_y} \cdot e^{-M \cdot t_{sf}}$
2. $MMB_{m_y} = \left[MMB_{f_y} - RM_y - DM_y \right] \cdot e^{-M \cdot t_{fm}}$

where MMB_{f_y} is the MMB in year y just prior to the fishery, M is natural mortality, RM_y is retained mortality on MMB in the directed fishery in year y, DM_y is discard mortality on MMB (**not** on all crab) in all fisheries in year y, t_{sf} is the time between the survey and the fishery, and t_{fm} is the time between the fishery and mating.

For the assessment year, the fishery has not yet occurred so RM and DM are unknown. The amount of fishing mortality presumably depends on the (as yet-to-be-determined) overfishing limit, so an iterative procedure is used to estimate MMB-at-mating for the fishery year. This procedure involves:

1. “guess” a value for F_{OFL}, the directed fishing mortality rate that yields OFL ($F_{OFL_{max}} = \gamma \cdot M$ is used)
2. determine the OFL corresponding to fishing at F_{OFL} using the following equations:
    - $MMB_f = MMB_s \cdot e^{-M \cdot t_{sf}}$
    - $RM_{OFL} = \left(1 - e^{-F_{OFL}} \right) \cdot MMB_s \cdot e^{-M \cdot t_{sf}}$
    - $DM_{OFL} = \theta \cdot \frac{MMB_f}{p_{male}}$
    - $OFL = RM_{OFL} + DM_{OFL}$
3. project MMB-at-mating from the “current” survey MMB and the OFL:
    - $MMB_m = \left[MMB_{f_y} - \left(RM_{OFL} + p_{male} \cdot DM_{OFL} \right) \right] \cdot e^{-M \cdot t_{fm}}$
4. use the harvest control rule to determine the F_{OFL} corresponding to the projected MMB-at-mating.

5. update the "guess" in 1. for the result in 4.
6. repeat steps 2-5 until the process has converged, yielding self-consistent values for F_{OFL} and MMB-at-mating.

where p_{male} is the assumed fraction of discard mortality on males. Note that this procedure determines the OFL for the assessment year as well as the current MMB-at-mating. Also note that, while the retained mortality RM_{OFL} is based on the F_{OFL}, the discard mortality DM_{OFL} is assumed to be proportional to the MMB at the time of the fishery, with proportionality constant $\frac{\theta}{p_{male}}$. The constant θ is determined by the average ratio of discard mortality on MMB (DM_{MMB}) to MMB at the time of the fishery (MMB_f) over a recent time interval:

$$\theta = \frac{1}{N} \sum_y \frac{DM_{MMB_y}}{MMB_{f_y}}$$

where the sum is over the last N years. In addition, DM_{MMB} is assumed to be proprtional to total discard mortality, with that proportionality given by the percenatge of males in the stock.

Data

Data from the following files were used in this assessment:

- fishery data: ./Data2017AM.Fisheries.csv
- survey data : ./Data2017AM.Surveys.csv

The following figures illustrate the time series of retained PIBKC in the directed fishery and PIBKC incidentally taken in the crab and groundfish fisheries (i.e., bycatch):

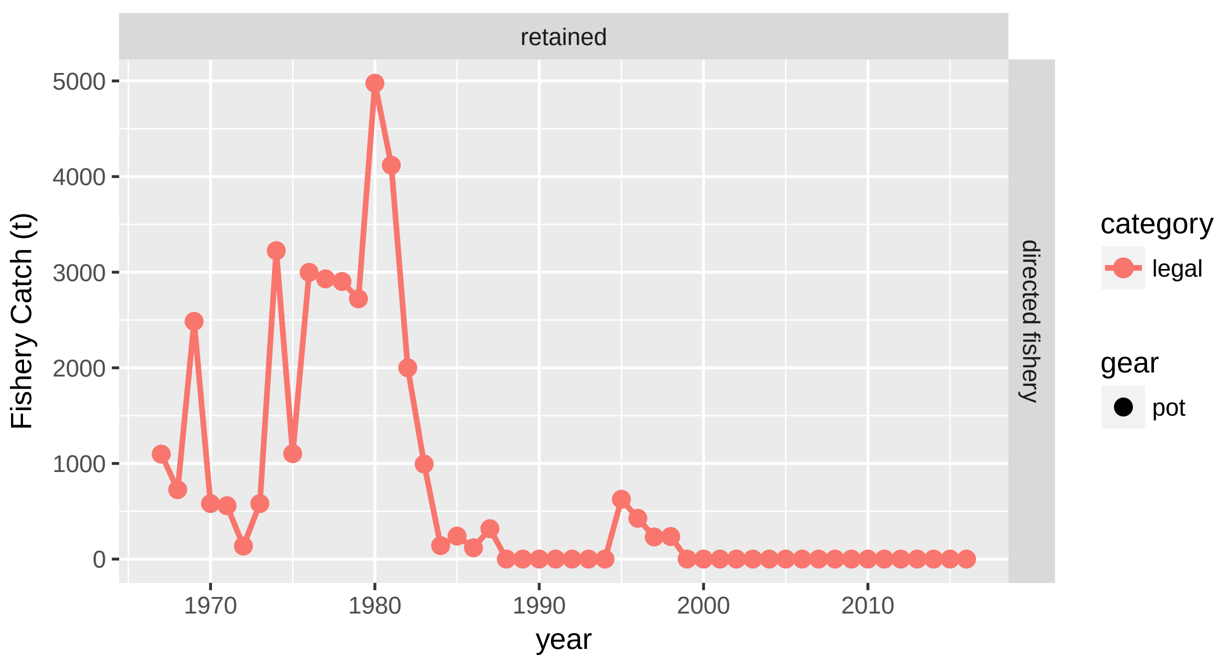

Figure 1: Time series of retained PIBKC catch in the directed fishery.

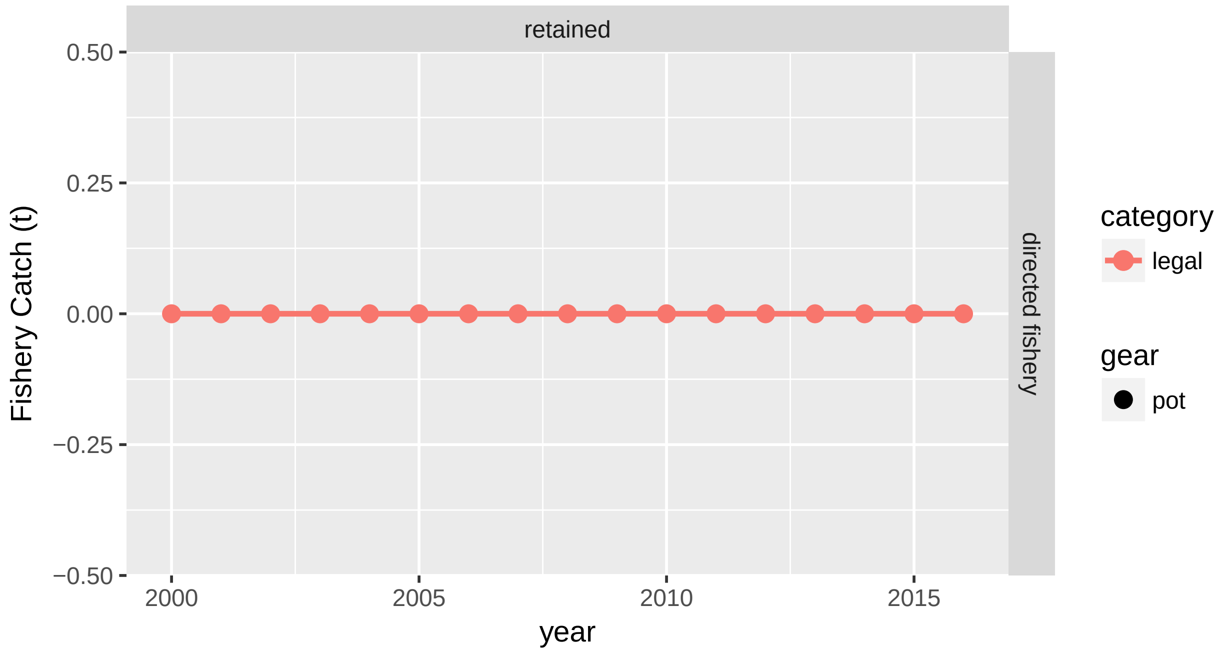

Figure 2: Time series of retained PIBKC catch in the directed fishery (recent time period).

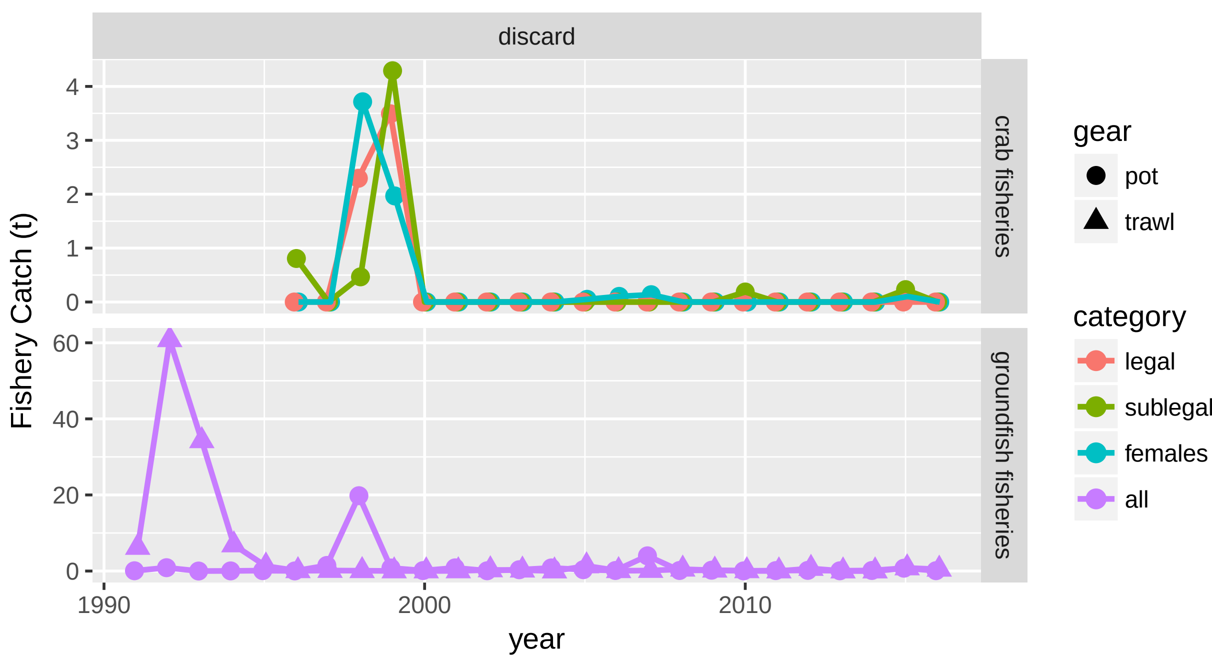

Figure 3: Time series of PIBKC bycatch in the crab and groundfish fisheries.

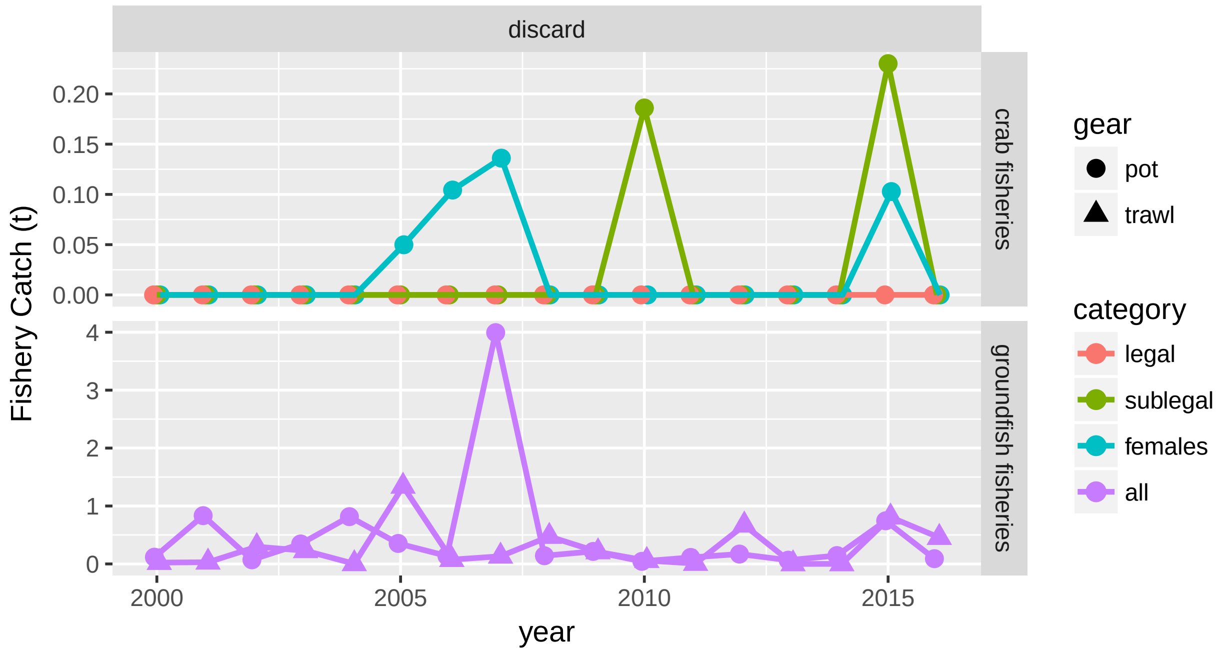

Figure 4: Time series of PIBKC bycatch in the crab and groundfish fisheries (recent time period).

The following figures illustrate the time series of PIBKC survey biomass in the NMFS EBS bottom trawl survey:

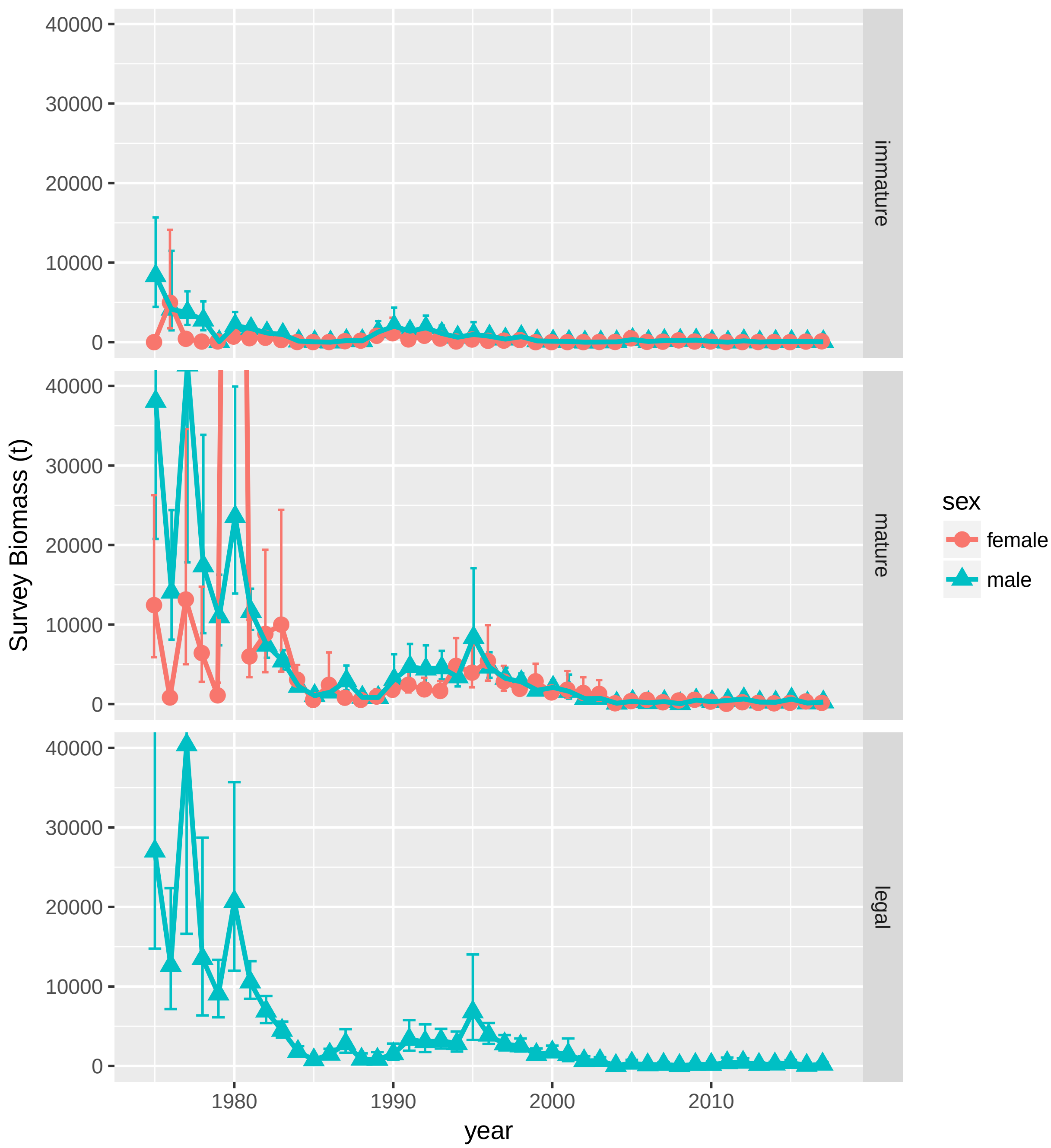

Figure 5: Time series of NMFS EBS bottom trawl survey biomass for PIBKC. Confidence intervals shown are 80% CI's, assuming lognormal error distributions.

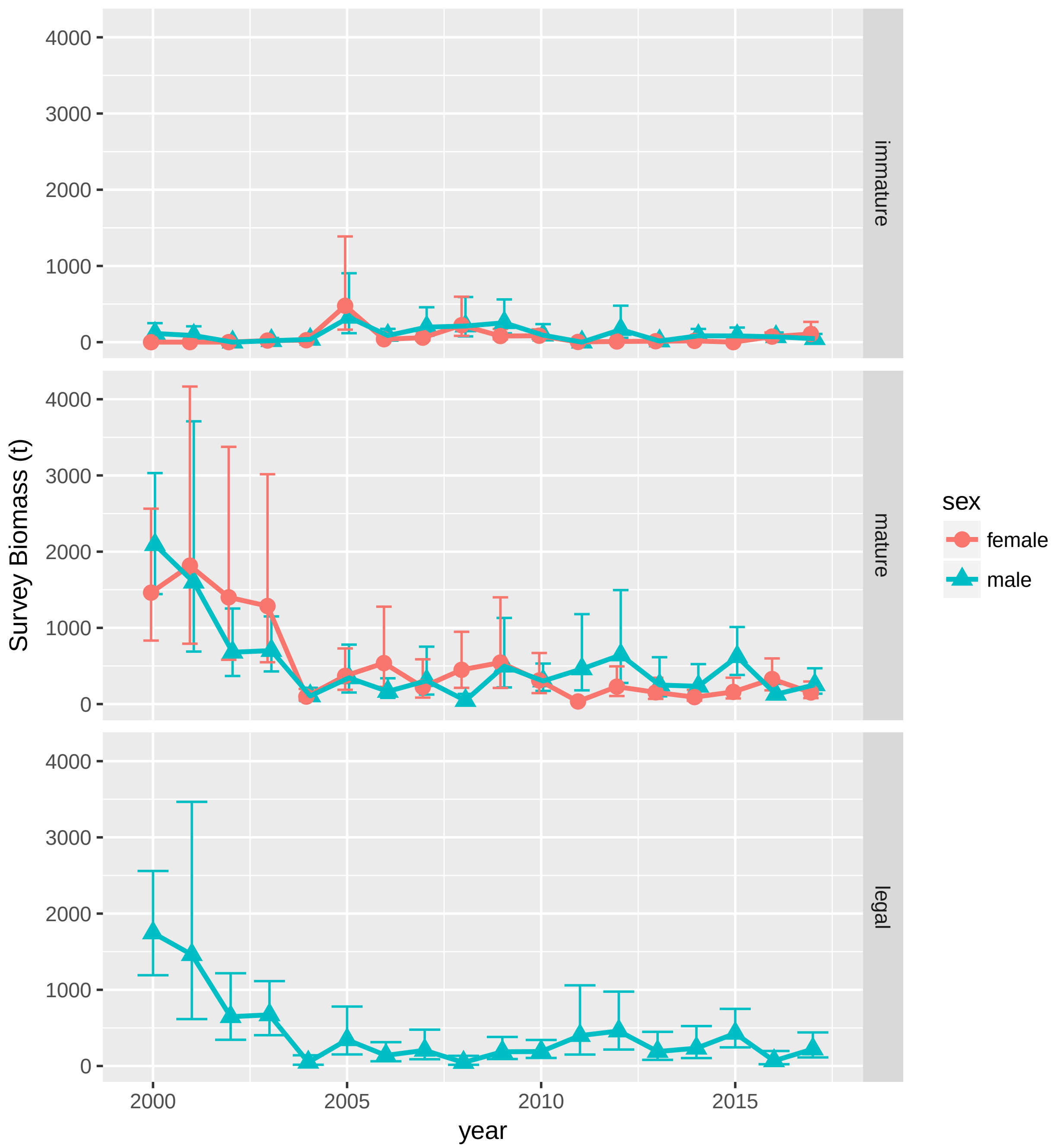

Figure 6: Time series of NMFS EBS bottom trawl survey biomass for PIBKC (recent time period). Confidence intervals shown are 80% CI's, assuming lognormal error distributions.

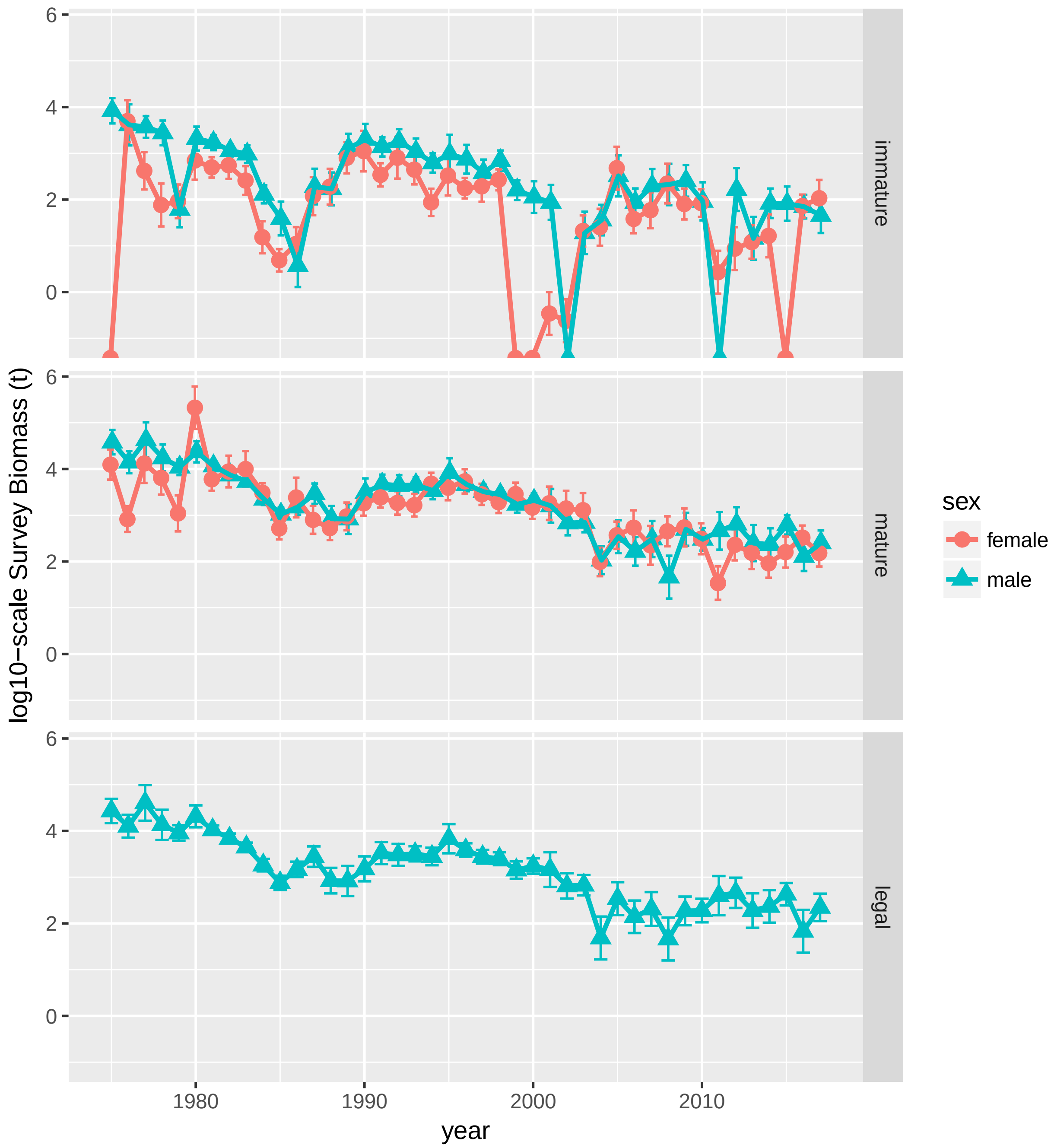

Figure 7: Log10-scale time series for the NMFS EBS bottom trawl survey biomass for PIBKC. Confidence intervals shown are 80% CI's, assuming lognormal error distributions.

Survey smoothing

For PIBKC, the variances associated with annual survey estimates of MMB are so large that, prior to estimating B_{MSY} and "current" MMB-at-mating, the survey MMB time series is first smoothed to reduce overall variability. Starting with the 2015 assessment (Stockhausen, 2015), a random effects (RE) model based on code developed by Jim Ianelli (NOAA/NMFS/AFSC) has been used to perform the smoothing. This is a statistical approach which models annual log-scale changes in "true" survey MMB as a random walk process using

$$< ln(MMB_s) >_y = < ln(MMB_s) >_{y-1} + \epsilon_y, \text{ where } \epsilon_y \sim N(0, \phi^2)$$

as the state equation and

$$ln(MMB_{s_y}) = < ln(MMB_s) >_y + \eta_y, \text{ where } \eta_y \sim N(0, \sigma_{s_y}^2)$$

as the observation equation, where $< ln(MMB_s) >_y$ is the estimated "true" log-scale survey MMB in year y, ϵ_y represents normally-distributed process error in year y with standard deviation ϕ, MMB_{s_y} is the observed survey MMB in year y, η_y represents normally-distributed ln-scale observation error, and σ_{s_y} is the log-scale survey MMB standard deviation in year y. The MMB_s's and σ_s's are observed quantities, the $< ln(MMB_s) >$'s and ϕ are estimated parameters, and the ϵ's are random effects (essentially nuisance parameters) that are integrated out in the solution.

Parameter estimates are obtained by minimizing the objective function

$$\Lambda = \sum_y \left[ln(2\pi\phi) + \left(\frac{< ln(MMB_s) >_y - < ln(MMB_s) >_{y-1}}{\phi} \right)^2 \right] + \sum_y \left(\frac{ln(MMB_{s_y}) - < ln(MMB_s) >_y}{\sigma_{s_y}} \right)^2$$

The model is coded in C++ and uses AD Model Builder C++ libraries (Fournier et al., 2012) to minimize the objective function.

Smoothing results

For comparison, the raw and RE-smoothed survey MMB time series are shown below in Figures 8-10, on both arithmetic and natural log scales:

Figure 8: Arithmetic-scale raw and smoothed survey MMB time series. Confidence intervals shown are 80% CIs, assuming lognormal error distributions.

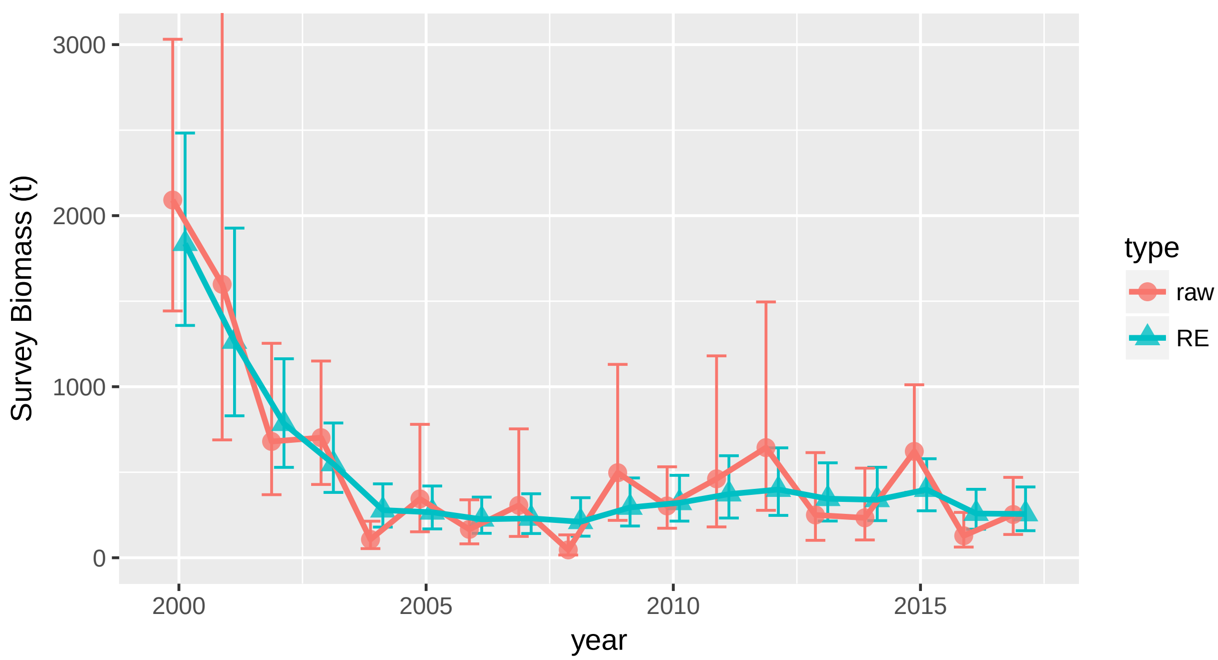

Figure 9: Arithmetic-scale raw and smoothed survey MMB time series, since 2000. Confidence intervals shown are 80% CIs, assuming lognormal error distributions.

Figure 10: Log-scale raw and smoothed survey MMB time series. Confidence intervals shown are 80% CIs, assuming lognormalerror distributions.

Status determination

Overfishing status

For PIBKC, the total fishing mortality in 2016/17 was 0.3820875 t while the OFL was 1.16 t. Thus, overfishing did not occur in 2016/17.

Overfished status

As discussed previously, overfished status is determined by the ratio $B/B_{MSY_{proxy}}$: the stock is overfished if the ratio is less than 0.5, where B is taken as "current" MMB-at-mating. For PIBKC, $B_{MSY_{proxy}}$ is obtained by averaging estimated MMB-at-mating over the period [1980/81-1984/85,1990/91-1997/98]. Following recommendations made by the CPT and SSC in 2015 (CPT, 2015; SSC, 2015), B and $B_{MSY_{proxy}}$ are based on MMB-at-mating calculated using the RE-smoothed time series of survey biomass projected forward to mating time.

MMB-at-mating

For comparison, time series for MMB-at-mating using both the raw (unsmoothed) survey MMB time series and the RE-smoothed survey MMB time series were calculated. The results are shown below in Figures 12 and 13:

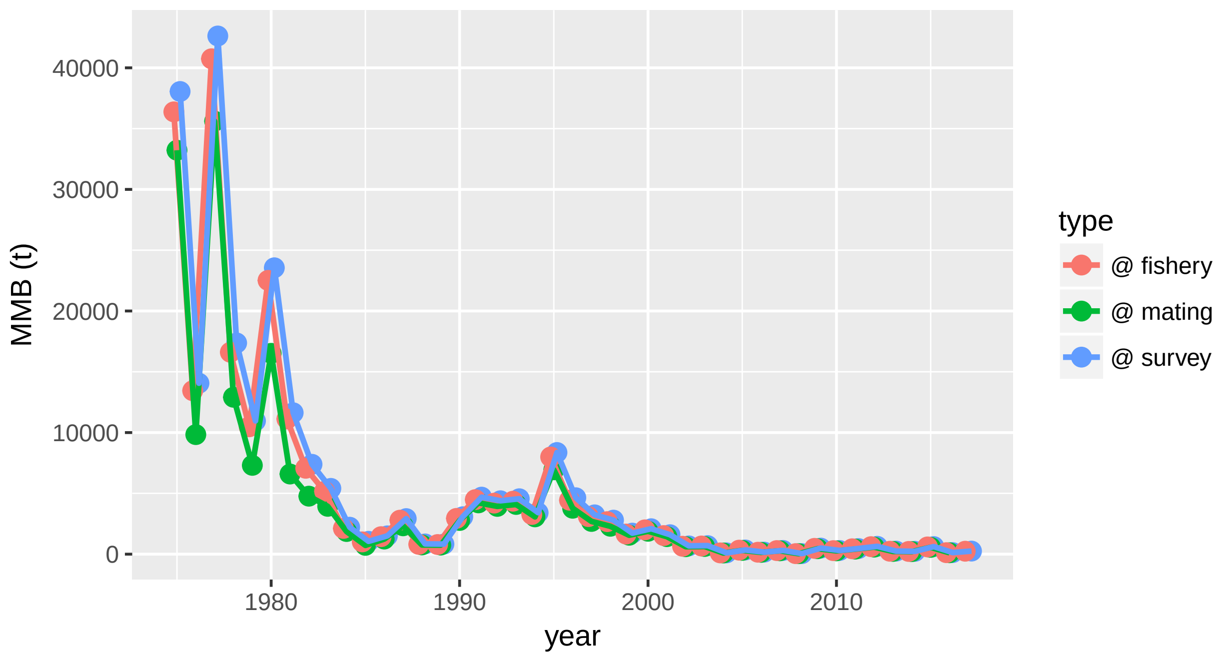

Figure 11: Estimated time series for MMB at the time of the survey (no smoothing), at the time of the fishery, and at the time of mating.

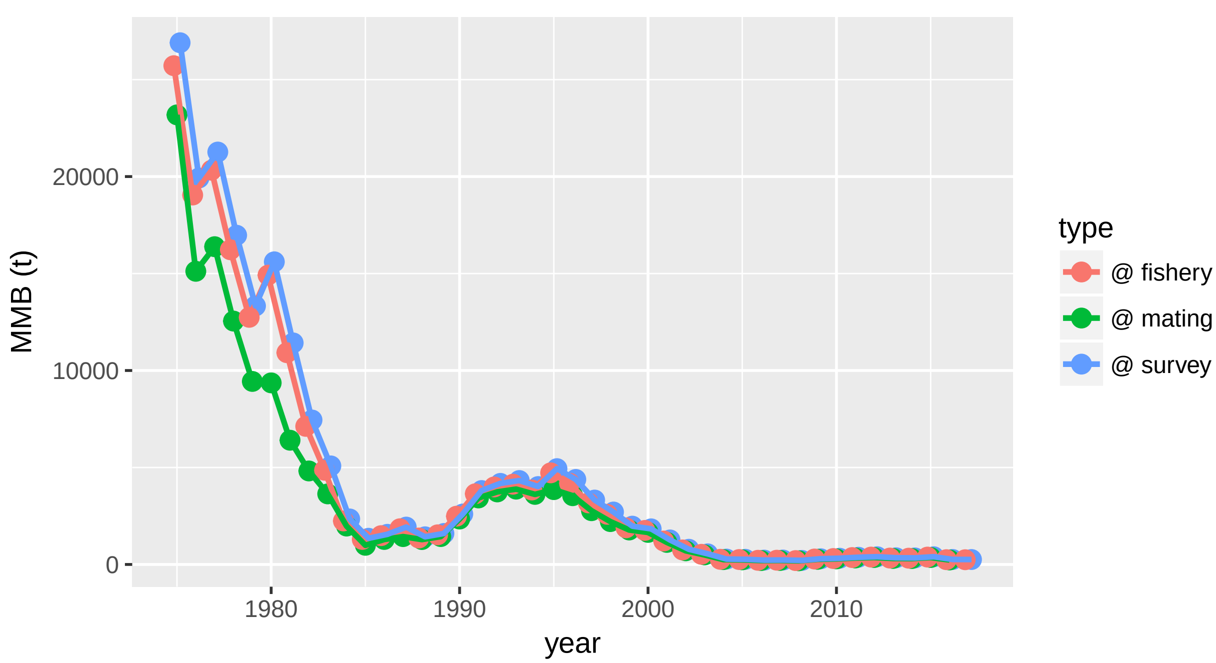

Figure 12: Estimated time series for MMB using the RE method at the time of the survey (the random effects time series), at the time of the fishery, and at the time of mating.

Values for $B_{MSY_{proxy}}$ and the estimated current (2017) MMB *at the time of the survey* from the raw survey data and the RE-smoothed results are:

Table 1: Estimated $B_{MSY_{proxy}}$ and current MMB at the time of the survey, using the raw survey data and the RE-smoothed data.

Estimation Type	Current survey MMB (t)	$B_{MSY_{proxy}}$ (t)
raw data	253	$5,012$
RE-smoothed	256	$4,108$

The value above for $B_{MSY_{proxy}}$ using the raw data is shown for illustration only. As noted previously, $B_{MSY_{proxy}}$ for this assessment is based on averaging the MMB-at-mating calculated from the RE-smoothed survey MMB (i.e., 4107.8663144 t).

Values for θ, used in the projected MMB calculations, based on averaging over the last three years, are:

Table 2: Estimated values for the *heta* coefficient.

	Estimation Type	θ
1	raw data	0.0007627
2	RE-smoothed	0.0006203

Results from the calculations for B ("current" MMB), overfished status, and an illustrative Tier 4-based OFL for 2017/18 (not used for PIBKC) are:

Table 3: More results from the OFL determination.

	quantity	units	raw.data	RE.smoothed
1	B ("current" MMB)	t	227.41	230.21
2	B_{MSY}	t	5,012.14	4,107.87
3	stock status	–	overfished	overfished
4	F_{OFL}	$year^{-1}$	0.00	0.00
5	RM_{OFL}	t	0.00	0.00
6	DM_{OFL}	t	0.37	0.30
7	OFL	t	0.37	0.30

Because B/B_{MSY} using RE-smoothed MMB-at-mating from the Table above is 0.056, the stock is overfished. Furthermore, because $B/B_{MSY} < \beta(= 0.25)$, directed fishing on PIBKC is prohibited.

Tables

Fishery data

Table 4: Annual retained catch biomass and bycatch (not mortality; in t), as available, in the directed fishery, the other crab fisheries, and the groundfish fisheries.

	crab fisheries			directed fishery	groundfish fisheries	
		pot		pot	pot	trawl
		discard		retained	discard	discard
	females	legal	sublegal	legal	all	all
year	t	t	t	t	t	t
1966	0.0000	NA	NA	0.0000	0.0000	NA
1967	NA	NA	NA	1,097.6928	NA	NA
1968	NA	NA	NA	725.7473	NA	NA
1969	NA	NA	NA	2,485.6846	NA	NA
1970	NA	NA	NA	580.5979	NA	NA
1971	NA	NA	NA	557.9183	NA	NA
1972	NA	NA	NA	136.0776	NA	NA
1973	NA	NA	NA	580.5979	NA	NA
1974	NA	NA	NA	3,225.0397	NA	NA
1975	NA	NA	NA	1,102.2288	NA	NA
1976	NA	NA	NA	2,998.2437	NA	NA
1977	NA	NA	NA	2,930.2049	NA	NA
1978	NA	NA	NA	2,902.9894	NA	NA
1979	NA	NA	NA	2,721.5525	NA	NA
1980	NA	NA	NA	4,975.9052	NA	NA
1981	NA	NA	NA	4,118.6161	NA	NA
1982	NA	NA	NA	2,000.3411	NA	NA
1983	NA	NA	NA	993.3667	NA	NA
1984	NA	NA	NA	140.6135	NA	NA
1985	NA	NA	NA	240.4038	NA	NA
1986	NA	NA	NA	117.9339	NA	NA
1987	NA	NA	NA	317.5145	NA	NA
1988	NA	NA	NA	0.0000	NA	NA
1989	NA	NA	NA	0.0000	NA	NA
1990	NA	NA	NA	0.0000	NA	NA
1991	NA	NA	NA	0.0000	0.0670	6.1990
1992	NA	NA	NA	0.0000	0.8790	60.7910
1993	NA	NA	NA	0.0000	0.0000	34.2320
1994	NA	NA	NA	0.0000	0.0350	6.8560
1995	NA	NA	NA	625.9571	0.1080	1.2840
1996	0.0000	0.0000	0.8074	426.3766	0.0310	0.0670
1997	0.0000	0.0000	0.0000	231.3320	1.4620	0.1300
1998	3.7149	2.2952	0.4672	235.8679	19.8000	0.0790
1999	1.9686	3.4927	4.2910	0.0000	0.7950	0.0200
2000	0.0000	0.0000	0.0000	0.0000	0.1160	0.0230
2001	0.0000	0.0000	0.0000	0.0000	0.8330	0.0290
2002	0.0000	0.0000	0.0000	0.0000	0.0710	0.2970
2003	0.0000	0.0000	0.0000	0.0000	0.3450	0.2270
2004	0.0000	0.0000	0.0000	0.0000	0.8160	0.0020
2005	0.0499	0.0000	0.0000	0.0000	0.3530	1.3390
2006	0.1043	0.0000	0.0000	0.0000	0.1380	0.0740
2007	0.1361	0.0000	0.0000	0.0000	3.9930	0.1320
2008	0.0000	0.0000	0.0000	0.0000	0.1410	0.4730
2009	0.0000	0.0000	0.0000	0.0000	0.2156	0.2068
2010	0.0000	0.0000	0.1860	0.0000	0.0443	0.0563
2011	0.0000	0.0000	0.0000	0.0000	0.1117	0.0071
2012	0.0000	0.0000	0.0000	0.0000	0.1699	0.6688
2013	0.0000	0.0000	0.0000	0.0000	0.0646	0.0000
2014	0.0000	0.0000	0.0000	0.0000	0.1443	0.0001
2015	0.1028	0.0000	0.2301	0.0000	0.7443	0.8078
2016	0.0000	0.0000	0.0000	0.0000	0.0904	0.4550

Survey data

Table 5: Input ('raw') male survey abundance data (numbers of crab).

	immature		legal		mature		total	
year	value	cv	value	cv	value	cv	value	cv
1975	8, 475, 780.89	0.57	9, 051, 485.73	0.50	28, 435, 755.89	1.11	36, 911, 536.79	1.07
1976	12, 328, 947.42	1.92	4, 012, 289.16	0.47	5, 551, 254.42	0.96	17, 880, 201.84	1.50
1977	5, 067, 465.88	1.28	11, 768, 927.37	0.77	26, 924, 033.45	1.60	31, 991, 499.33	1.48
1978	2, 482, 381.42	1.50	3, 922, 873.85	0.62	12, 067, 151.89	1.16	14, 549, 533.30	1.08
1979	221, 771.00	1.42	3, 017, 118.91	0.31	5, 276, 802.27	1.14	5, 498, 573.27	1.09
1980	3, 513, 951.44	1.24	6, 244, 057.67	0.42	190, 745, 260.90	1.39	194, 259, 212.34	1.38
1981	2, 925, 999.23	0.73	3, 245, 951.07	0.18	9, 267, 921.40	0.62	12, 193, 920.63	0.63
1982	2, 247, 538.58	0.80	2, 071, 467.90	0.19	10, 190, 817.25	0.83	12, 438, 355.84	0.80
1983	1, 494, 458.75	0.90	1, 321, 394.69	0.17	11, 159, 269.86	0.97	12, 653, 728.61	0.98
1984	983, 046.34	0.91	558, 226.46	0.25	3, 539, 833.29	0.60	4, 522, 879.63	0.58
1985	327, 846.69	1.14	270, 241.72	0.29	914, 260.33	0.72	1, 242, 107.02	0.63
1986	55, 588.48	1.70	460, 310.63	0.31	2, 582, 129.95	1.20	2, 637, 718.43	1.18
1987	1, 023, 070.70	1.58	830, 150.65	0.42	1, 573, 658.67	1.00	2, 596, 729.37	0.91
1988	2, 135, 682.52	1.71	237, 867.82	0.51	703, 331.18	0.99	2, 839, 013.70	1.35
1989	6, 150, 862.84	1.33	239, 947.52	0.62	1, 381, 703.37	1.28	7, 532, 566.21	1.16
1990	4, 627, 193.67	1.51	571, 708.33	0.54	3, 516, 258.12	1.17	8, 143, 451.79	1.13
1991	2, 725, 893.73	0.84	1, 237, 558.37	0.44	4, 781, 533.72	0.78	7, 507, 427.45	0.70
1992	4, 233, 139.11	1.51	1, 154, 465.28	0.45	4, 084, 797.20	0.91	8, 317, 936.31	1.00
1993	2, 364, 196.25	1.13	1, 114, 300.52	0.30	3, 658, 157.09	0.76	6, 022, 353.33	0.72
1994	783, 283.02	0.95	935, 268.63	0.34	6, 341, 478.39	0.78	7, 124, 761.41	0.77
1995	1, 805, 281.89	1.81	2, 186, 408.91	0.62	7, 140, 267.33	1.12	8, 945, 549.23	1.17
1996	995, 165.22	1.04	1, 269, 274.66	0.26	6, 757, 837.30	0.77	7, 753, 002.53	0.80
1997	787, 577.26	1.19	932, 852.28	0.28	3, 815, 669.55	0.72	4, 603, 246.80	0.73
1998	1, 449, 688.57	0.89	797, 187.26	0.25	2, 796, 606.53	0.69	4, 246, 295.10	0.67
1999	159, 535.74	0.37	452, 740.30	0.34	3, 373, 234.05	0.82	3, 532, 769.79	0.82
2000	163, 834.62	0.56	527, 589.35	0.30	2, 088, 120.40	0.76	2, 251, 955.02	0.77
2001	111, 434.07	1.65	445, 863.41	0.74	2, 219, 704.16	1.46	2, 331, 138.23	1.43
2002	18, 729.46	1.00	207, 145.98	0.49	1, 447, 328.02	1.27	1, 466, 057.48	1.25
2003	112, 599.69	1.20	213, 572.37	0.40	1, 349, 151.10	1.15	1, 461, 750.78	1.06
2004	185, 710.36	1.22	15, 583.88	1.00	117, 939.32	1.17	303, 649.68	0.93
2005	4, 249, 450.99	1.96	91, 932.30	0.71	381, 129.58	1.28	4, 630, 580.58	1.81
2006	251, 165.41	1.04	38, 242.00	0.70	485, 119.46	1.33	736, 284.87	1.04
2007	368, 647.45	1.45	54, 402.91	0.75	275, 842.91	1.75	644, 490.36	1.23
2008	576, 037.92	1.83	18, 255.62	1.00	455, 624.48	1.66	1, 031, 662.41	1.61
2009	420, 006.90	1.24	68, 117.04	0.59	725, 721.22	1.55	1, 145, 728.13	1.43
2010	266, 783.19	1.40	64, 702.83	0.48	379, 492.70	1.18	646, 275.89	1.23
2011	18, 089.34	1.00	129, 097.71	0.87	202, 037.20	1.49	220, 126.54	1.36
2012	229, 204.82	2.00	164, 164.90	0.68	584, 327.37	1.56	813, 532.19	1.57
2013	121, 694.76	1.70	68, 726.09	0.80	254, 660.86	1.49	376, 355.62	1.18
2014	118, 710.86	1.59	91, 855.85	0.71	166, 223.38	1.31	284, 934.24	1.07
2015	75, 575.44	0.77	124, 591.54	0.45	436, 094.37	1.02	511, 669.81	1.06
2016	225, 711.04	1.02	19, 344.90	1.00	378, 612.24	1.08	604, 323.27	0.99
2017	256, 098.21	1.52	71, 937.24	0.59	252, 444.72	1.04	508, 542.93	0.99

Table 6: Input ('raw') male survey biomass data, in t.

	immature		legal		mature		total	
year	value	cv	value	cv	value	cv	value	cv
1975	8,340.95	0.52	27,016.47	0.50	38,053.59	0.50	46,394.54	0.47
1976	4,128.67	0.94	12,648.94	0.47	14,058.93	0.45	18,187.61	0.45
1977	3,713.34	0.44	40,365.94	0.78	42,618.32	0.77	46,331.66	0.73
1978	2,765.31	0.51	13,516.82	0.64	17,369.71	0.56	20,135.02	0.51
1979	61.27	0.79	9,039.95	0.31	10,959.38	0.32	11,020.66	0.31
1980	2,083.76	0.49	20,678.62	0.45	23,552.92	0.43	25,636.68	0.42
1981	1,704.25	0.30	10,553.54	0.17	11,628.25	0.17	13,332.49	0.18
1982	1,151.96	0.23	6,893.43	0.19	7,388.96	0.19	8,540.92	0.17
1983	962.34	0.36	4,474.40	0.17	5,408.73	0.18	6,371.08	0.19
1984	129.72	0.36	1,824.02	0.25	2,215.66	0.23	2,345.38	0.22
1985	39.02	0.73	755.50	0.28	1,054.79	0.27	1,093.81	0.26
1986	3.73	1.00	1,473.32	0.31	1,504.69	0.30	1,508.43	0.30
1987	191.45	0.78	2,781.34	0.41	2,923.38	0.41	3,114.84	0.40
1988	170.05	0.71	842.43	0.53	842.43	0.53	1,012.48	0.46
1989	1,274.88	0.62	827.50	0.64	827.50	0.64	2,102.37	0.55
1990	2,004.14	0.66	1,514.33	0.52	3,077.51	0.60	5,081.65	0.61
1991	1,377.43	0.39	3,325.77	0.45	4,689.67	0.39	6,067.10	0.37
1992	1,800.51	0.51	3,034.80	0.45	4,391.01	0.42	6,191.52	0.43
1993	1,088.50	0.54	3,202.55	0.30	4,555.60	0.31	5,644.10	0.30
1994	618.98	0.39	2,805.73	0.35	3,410.36	0.34	4,029.34	0.34
1995	967.73	0.86	6,786.93	0.62	8,360.23	0.60	9,327.96	0.63
1996	744.89	0.61	3,873.06	0.27	4,640.62	0.27	5,385.51	0.28
1997	381.39	0.55	2,765.39	0.27	3,232.58	0.28	3,613.97	0.29
1998	692.25	0.41	2,509.92	0.25	2,797.93	0.25	3,490.19	0.25
1999	160.65	0.40	1,426.16	0.35	1,729.24	0.34	1,889.89	0.33
2000	113.32	0.68	1,745.75	0.31	2,091.34	0.30	2,204.66	0.30
2001	87.07	0.76	1,460.92	0.76	1,598.74	0.73	1,685.81	0.73
2002	0.00	0.00	647.07	0.52	679.80	0.51	679.80	0.51
2003	19.06	0.98	671.20	0.41	702.01	0.40	721.07	0.39
2004	36.01	0.65	48.43	1.00	106.88	0.58	142.89	0.46
2005	325.78	0.94	344.06	0.71	344.06	0.71	669.84	0.59
2006	86.89	0.58	139.22	0.70	165.89	0.60	252.77	0.46
2007	196.77	0.74	205.56	0.73	306.46	0.80	503.23	0.66
2008	211.71	0.95	45.98	1.00	45.98	1.00	257.69	0.80
2009	254.30	0.68	186.51	0.60	497.11	0.71	751.41	0.70
2010	91.64	0.85	190.05	0.48	302.93	0.46	394.57	0.52
2011	0.00	0.00	398.98	0.89	461.36	0.84	461.36	0.84
2012	164.71	1.00	458.98	0.64	643.94	0.74	808.65	0.79
2013	14.53	1.00	189.92	0.75	250.14	0.80	264.66	0.75
2014	83.15	0.62	233.39	0.70	233.39	0.70	316.54	0.57
2015	81.69	0.75	428.26	0.46	621.71	0.39	703.40	0.39
2016	70.34	0.49	67.74	1.00	128.55	0.61	198.89	0.52
2017	45.20	0.77	222.52	0.57	252.78	0.51	297.98	0.47

Table 7: Input ('raw') female survey abundance data (numbers of crab).

	immature		mature		total	
year	value	cv	value	cv	value	cv
1975	0.00	0.00	13,147,586.68	0.61	13,147,586.68	0.61
1976	7,369,388.06	0.97	769,149.65	0.51	8,138,537.71	0.91
1977	851,600.68	0.82	13,880,050.65	0.86	14,731,651.34	0.86
1978	60,923.05	1.00	5,926,514.32	0.66	5,987,437.37	0.66
1979	142,416.25	0.72	1,168,934.53	0.81	1,311,350.78	0.77
1980	781,223.69	0.77	182,902,918.90	0.98	183,684,142.60	0.98
1981	826,523.82	0.41	5,433,490.77	0.44	6,260,014.59	0.42
1982	876,255.79	0.51	7,837,003.99	0.65	8,713,259.78	0.63
1983	463,726.39	0.54	9,307,968.75	0.78	9,771,695.14	0.76
1984	465,472.58	0.52	2,769,190.35	0.38	3,234,662.94	0.37
1985	260,081.29	0.54	486,184.43	0.44	746,265.72	0.36
1986	36,684.23	0.70	2,101,931.80	0.90	2,138,616.03	0.88
1987	401,529.77	0.74	670,478.72	0.58	1,072,008.49	0.48
1988	897,629.21	0.87	465,463.37	0.48	1,363,092.58	0.64
1989	2,636,098.81	0.74	1,141,755.85	0.66	3,777,854.65	0.58
1990	2,177,329.21	0.91	2,045,839.41	0.55	4,223,168.62	0.56
1991	805,450.59	0.46	2,767,448.02	0.42	3,572,898.61	0.35
1992	1,797,343.33	0.93	2,149,519.20	0.49	3,946,862.54	0.52
1993	880,672.33	0.61	1,782,656.74	0.45	2,663,329.07	0.38
1994	144,763.08	0.57	5,047,215.18	0.44	5,191,978.25	0.44
1995	658,479.28	0.92	4,038,555.59	0.52	4,697,034.87	0.49
1996	275,735.14	0.42	5,045,822.06	0.48	5,321,557.20	0.46
1997	320,343.56	0.67	2,614,373.74	0.42	2,934,717.30	0.39
1998	500,241.34	0.43	1,829,509.02	0.44	2,329,750.36	0.37
1999	0.00	0.00	2,755,975.76	0.49	2,755,975.76	0.49
2000	0.00	0.00	1,363,069.69	0.46	1,363,069.69	0.46
2001	18,516.37	1.00	1,697,465.09	0.75	1,715,981.46	0.74
2002	18,729.46	1.00	1,221,852.43	0.79	1,240,581.89	0.78
2003	67,328.63	0.48	1,120,254.01	0.76	1,187,582.64	0.72
2004	98,059.03	0.63	70,034.56	0.60	168,093.59	0.51
2005	2,268,112.83	1.00	289,197.28	0.56	2,557,310.11	0.89
2006	113,047.12	0.55	429,540.72	0.77	542,587.84	0.62
2007	122,482.70	0.73	165,762.60	0.90	288,245.30	0.59
2008	342,119.25	0.90	437,368.86	0.66	779,488.11	0.75
2009	152,290.08	0.61	477,095.11	0.82	629,385.19	0.76
2010	165,632.29	0.56	249,027.32	0.69	414,659.61	0.62
2011	18,089.34	1.00	36,511.72	0.70	54,601.06	0.56
2012	34,682.61	1.00	312,094.57	0.76	346,777.18	0.70
2013	45,343.64	0.70	150,299.88	0.63	195,643.52	0.53
2014	27,720.50	1.00	74,367.54	0.60	102,088.04	0.51
2015	0.00	0.00	202,464.39	0.65	202,464.39	0.65
2016	131,689.04	0.50	322,760.45	0.52	454,449.50	0.50
2017	187,859.97	0.75	161,799.38	0.53	349,659.35	0.54

Table 8: Input ('raw') female survey biomass data, in t.

	immature		mature		total	
year	value	cv	value	cv	value	cv
1975	0.00	0.00	12,442.27	0.64	12,442.27	0.64
1976	4,967.70	0.97	823.80	0.53	5,791.50	0.89
1977	418.58	0.83	13,153.87	0.88	13,572.45	0.87
1978	76.40	1.00	6,415.74	0.72	6,492.14	0.72
1979	91.67	0.73	1,097.29	0.79	1,188.96	0.76
1980	699.46	0.86	211,603.71	0.98	212,303.16	0.98
1981	497.16	0.41	5,986.82	0.47	6,483.97	0.46
1982	553.17	0.57	8,823.72	0.68	9,376.89	0.67
1983	258.05	0.61	9,989.87	0.79	10,247.93	0.78
1984	15.35	0.69	3,069.56	0.38	3,084.90	0.38
1985	4.87	0.46	519.81	0.45	524.67	0.44
1986	11.02	0.73	2,419.78	0.90	2,430.80	0.90
1987	118.72	0.86	794.61	0.58	913.33	0.53
1988	190.14	0.79	527.64	0.49	717.78	0.47
1989	800.78	0.67	944.75	0.58	1,745.53	0.50
1990	1,118.45	0.93	1,810.45	0.51	2,928.89	0.49
1991	342.70	0.48	2,433.24	0.41	2,775.93	0.38
1992	801.57	0.96	1,847.65	0.48	2,649.23	0.46
1993	444.39	0.62	1,647.13	0.46	2,091.51	0.40
1994	87.01	0.57	4,805.95	0.45	4,892.96	0.44
1995	331.03	0.90	3,947.94	0.52	4,278.97	0.50
1996	176.52	0.42	5,408.25	0.50	5,584.77	0.49
1997	193.64	0.66	2,834.78	0.43	3,028.42	0.41
1998	267.35	0.42	1,914.46	0.44	2,181.81	0.39
1999	0.00	0.00	2,868.27	0.47	2,868.27	0.47
2000	0.00	0.00	1,461.82	0.46	1,461.82	0.46
2001	0.34	1.00	1,816.35	0.72	1,816.69	0.72
2002	0.24	1.00	1,400.74	0.78	1,400.98	0.78
2003	20.94	0.67	1,286.42	0.75	1,307.36	0.73
2004	25.20	0.82	97.71	0.60	122.91	0.50
2005	477.27	1.00	369.83	0.57	847.10	0.61
2006	38.16	0.60	537.85	0.76	576.01	0.71
2007	58.77	0.79	223.43	0.88	282.19	0.71
2008	222.03	0.90	449.54	0.64	671.57	0.70
2009	80.22	0.66	544.69	0.85	624.91	0.82
2010	84.08	0.58	310.16	0.66	394.24	0.63
2011	2.69	1.00	34.14	0.73	36.83	0.67
2012	8.70	1.00	228.76	0.66	237.46	0.64
2013	12.06	0.72	153.85	0.70	165.91	0.65
2014	16.43	1.00	91.11	0.60	107.54	0.53
2015	0.00	0.00	159.65	0.66	159.65	0.66
2016	72.47	0.47	328.67	0.50	401.14	0.48
2017	106.89	0.81	152.11	0.56	259.01	0.53

Table 9: A comparison of estimates for MMB (in t) at the time of the survey.

		raw			RE	
year	value	lci	uci	value	lci	uci
1975	38,053.59	20,759.61	69,754.48	26,901.00	16,825.61	43,009.66
1976	14,058.93	8,103.53	24,391.05	19,926.60	13,388.82	29,656.78
1977	42,618.32	17,814.39	101,958.08	21,264.90	13,591.30	33,270.99
1978	17,369.71	8,912.49	33,852.16	16,974.60	11,333.27	25,424.00
1979	10,959.38	7,385.67	16,262.32	13,329.30	9,743.03	18,235.63
1980	23,552.92	13,894.39	39,925.46	15,605.10	11,032.07	22,073.75
1981	11,628.25	9,320.75	14,507.00	11,423.00	9,355.46	13,947.47
1982	7,388.96	5,824.58	9,373.50	7,448.55	6,051.74	9,167.76
1983	5,408.73	4,315.80	6,778.45	5,081.02	4,155.14	6,213.21
1984	2,215.66	1,659.01	2,959.08	2,347.24	1,840.91	2,992.84
1985	1,054.79	753.94	1,475.68	1,349.79	1,020.02	1,786.18
1986	1,504.69	1,029.62	2,198.96	1,555.26	1,156.67	2,091.20
1987	2,923.38	1,761.10	4,852.75	1,927.64	1,351.62	2,749.15
1988	842.43	445.93	1,591.49	1,427.29	946.09	2,153.24
1989	827.50	391.56	1,748.76	1,598.80	1,027.48	2,487.79
1990	3,077.51	1,512.59	6,261.49	2,602.58	1,717.52	3,943.72
1991	4,689.67	2,910.49	7,556.46	3,812.12	2,677.47	5,427.61
1992	4,391.01	2,612.05	7,381.55	4,181.16	2,939.68	5,946.94
1993	4,555.60	3,100.43	6,693.73	4,328.92	3,200.20	5,855.75
1994	3,410.36	2,219.61	5,239.91	4,017.00	2,906.92	5,551.00
1995	8,360.23	4,090.73	17,085.84	4,941.99	3,335.75	7,321.67
1996	4,640.62	3,308.54	6,509.03	4,384.30	3,316.32	5,796.22
1997	3,232.58	2,284.30	4,574.53	3,322.05	2,523.45	4,373.38
1998	2,797.93	2,042.57	3,832.65	2,704.95	2,085.48	3,508.43
1999	1,729.24	1,136.48	2,631.17	1,976.11	1,450.90	2,691.44
2000	2,091.34	1,442.89	3,031.19	1,836.48	1,358.21	2,483.16
2001	1,598.74	688.93	3,710.05	1,264.67	829.84	1,927.36
2002	679.80	368.60	1,253.75	784.02	528.41	1,163.28
2003	702.01	428.47	1,150.19	548.55	381.89	787.92
2004	106.88	53.46	213.67	278.26	179.24	432.00
2005	344.06	151.76	780.00	265.97	168.64	419.46
2006	165.89	81.25	338.67	224.99	142.84	354.39
2007	306.46	124.64	753.49	230.18	141.64	374.08
2008	45.98	15.82	133.66	210.46	126.20	350.98
2009	497.11	218.63	1,130.34	294.20	185.57	466.43
2010	302.93	172.57	531.78	321.26	214.21	481.79
2011	461.36	180.34	1,180.27	372.10	232.13	596.46
2012	643.94	277.26	1,495.58	398.87	247.63	642.49
2013	250.14	101.79	614.66	345.09	214.61	554.90
2014	233.39	103.97	523.89	338.82	217.04	528.91
2015	621.71	382.23	1,011.25	398.72	274.64	578.88
2016	128.55	62.34	265.09	258.43	166.93	400.10
2017	252.78	135.99	469.85	255.86	158.16	413.90

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