Pribilof Island golden king crab
2018 Tier 5 Assessment
May 2017 CPT

- **Responses to the most recent two sets of SSC and CPT comments specific to the assessment:**
  - CPT, May 2016:
    - *"A Tier 4 assessment based on a random effects model was presented at the September 2015 meeting. Information on mature and legal male biomass from the slope trawl surveys was only available for three years (2008, 2010, and 2012), and the model runs did not appear to be able to estimate a process error term with the available data. A slope trawl survey is planned for the summer of 2016 and the CPT will re-evaluate the model with the new survey results in January or May 2017………."*
      - Response: The author has conducted the preliminary model analysis with the 2016 survey included, and includes those results in an updated discussion paper.

- SSC, June 2016:
  - *"In June 2015, the SSC requested that the author approach the harvester about whether they would voluntarily allow confidential data to be presented in assessments. However, this was not done. The SSC reiterates this request."*
    - Still not done. No directed fishery since 2014. In progress. Waivers have been obtained from harvesters for the confidential seasons and discussions are in progress as to which processor waivers are needed (M. Westphal, ADF&G, Dutch Harbor, *pers. comm.*, 14 April 2017).
  - *"Finally, the SSC reiterates last year's request for NMFS to assess the feasibility to provide groundfish PSC data for PIGKC by calendar year".*
    - Groundfish bycatch data for PIGKC is provided by NMFS by calendar year from 2009 to 2016, and is included in this assessment.
  - *"A Tier 4 assessment based on a random effects model was presented to the CPT in September 2015, but it was unable to estimate process error. That Tier 4 assessment was based on 5 years of slope trawl surveys. The plan is to reevaluate the random effects model after results from the 2016 slope trawl survey become available in 2017. The SSC looks forward to a future Tier 4 assessment."*
    - Not done. The author reran the model with 2016 slope survey data with an associated discussion paper. However, the author does not present this in relation to a Tier 4 or modified Tier 5 assessment. The Analyst involved previously (Gaeuman) has since left the department, thus continuity is this process has been interrupted.
- CPT, September 2015 and 2016:
  - *"The CPT recommends the random effects model be re-evaluated after results from the 2016 slope survey are available."*
    - Response: See above.
- SSC, October 2015:
  - *"The SSC concurs with the CPT recommendation"* [*"that the random effects model be re-evaluated after results from the 2016 slope survey are available"*]
    - Response: Okay. See above.

5. Management performance:

No overfished determination (i.e., MSST) has been made for this stock, although approaches to using data from the biennial NMFS-AFSC eastern Bering Sea upper continental slope surveys have been presented to and considered by the Crab Plan Team (Gaeuman 2013a, 2013b, Pengilly 2015; see Appendices A2 and A3). No vessels participated in the 2015 or 2016 directed fishery (i.e., retained catch= 0 t; 0 lb) and no bycatch was observed in crab fisheries in these years; 0.24 t of fishery mortality occurred during groundfish fisheries in 2016. Overfishing did not occur in 2016. The GHL for the 2018 has yet to be established (M.Stichert, ADF&G, Kodiak, *pers. comm.*, 1 April 2017). The 2018 OFL and ABC in the table below are the author's recommendations.

Management Performance Table (values in t)

Calendar Year	MSST	Biomass (MMB)	GHL[a]	Retained Catch	Total Catch[b]	OFL	ABC
2013	N/A	N/A	68	Conf.[c]	Conf.[c]	90.7	81.6
2014	N/A	N/A	68	Conf.[c]	Conf.[c]	90.7	81.6
2015	N/A	N/A	59	0	1.92	91	68
2016	N/A	N/A	59	0	0.24	91	68
2017	N/A	N/A	59			93	70
2018	N/A	N/A				93	70

a. Guideline harvest level, established in lb and converted to t.
b. Total retained catch plus estimated bycatch mortality of discarded catch during crab fisheries and bycatch mortality due to groundfish fisheries are included here, but not for 2013 and 2014 because the directed fishery is confidential.
c. Confidential under Sec. 16.05.815 (SOA statute). GHL not attained.

Management Performance Table (values in lb)

Calendar Year	MSST	Biomass (MMB)	GHL[a]	Retained Catch	Total Catch[b]	OFL	ABC
2013	N/A	N/A	150,000	Conf.[c]	Conf.[c]	0.20[d]	0.18[d]
2014	N/A	N/A	150,000	Conf.[c]	Conf.[c]	0.20[d]	0.18[d]
2015	N/A	N/A	130,000	0	4,229	0.20[d]	0.15[d]
2016	N/A	N/A	130,000	0	534	0.20[d]	0.15[d]
2017	N/A	N/A	130,000			0.20[d]	0.15[d]
2018						204,527	153,395

a. Guideline harvest level.
b. Total retained catch plus estimated bycatch mortality of discarded catch during crab fisheries and groundfish fisheries. Estimates of annual bycatch mortality during 1991/92–2016 groundfish fisheries are ≤19,480 lb, with an average of 5,098 lb.
c. Confidential under Sec. 16.05.815 (SOA statute). GHL not attained.
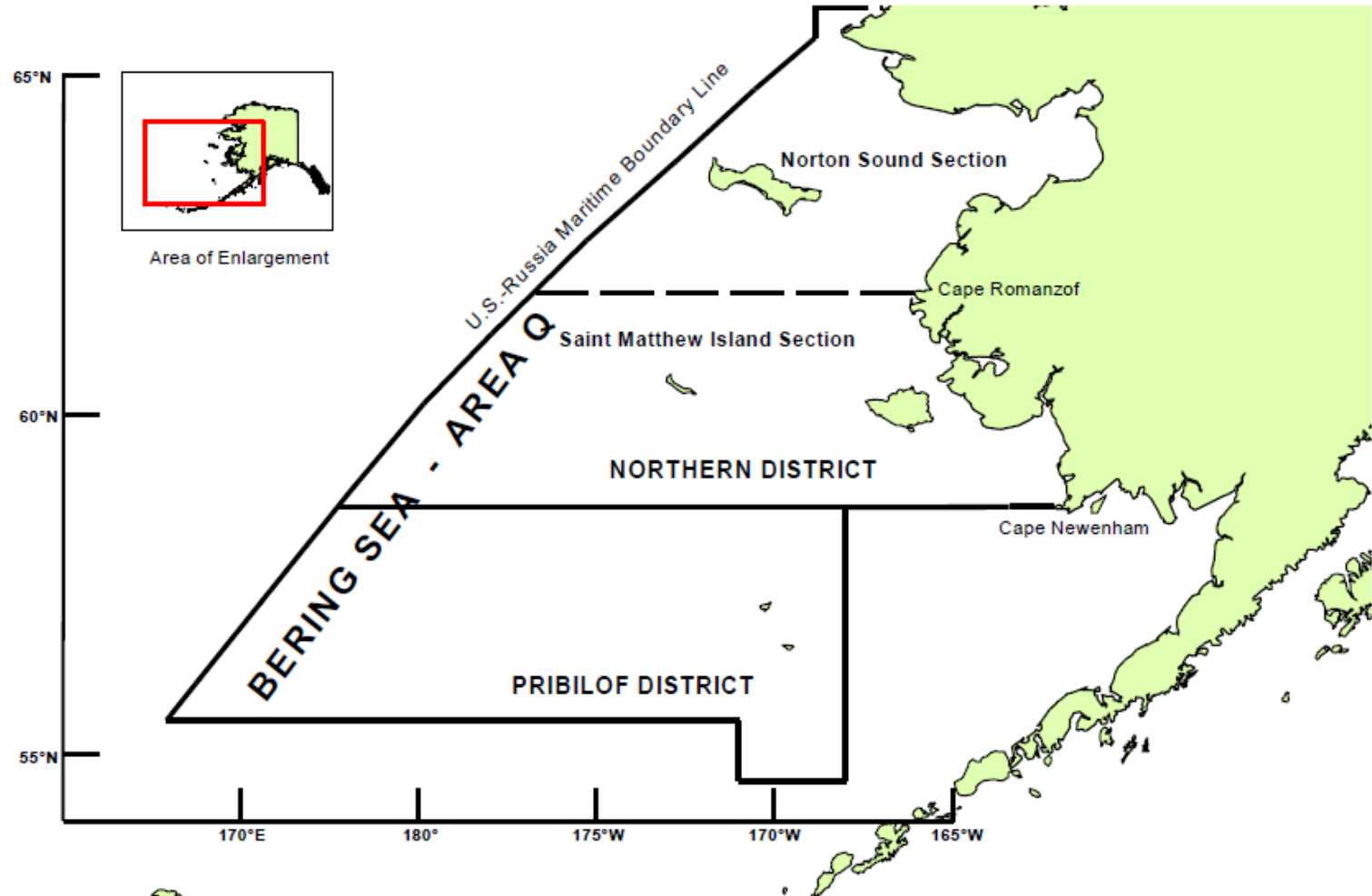d. Established in millions of lb to the nearest 0.01-million lb.

Figure 1. King crab Registration Area Q (Bering Sea), showing borders of the Pribilof District (from Figure 2-4 *in* Leon et al. 2017).
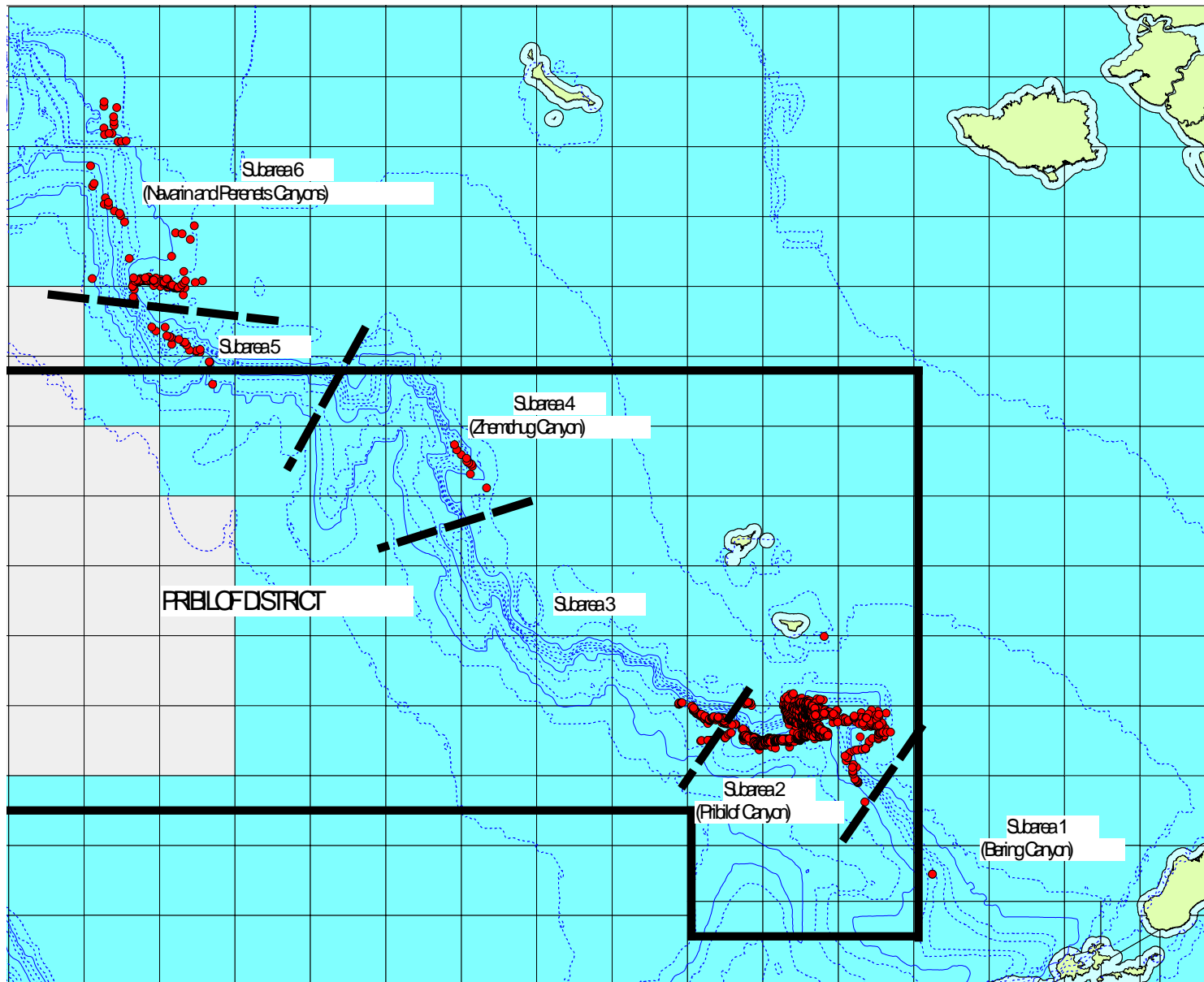
Figure 7. Locations of all pots sampled by observers during Bering Sea golden king crab fisheries (n = 6,104), 1992–2014; pots north of the Pribilof District northern boundary were fished during the Northern District – Saint Matthew Island Section fishery; squares are 1° longitude x 30' latitude State statistical areas.
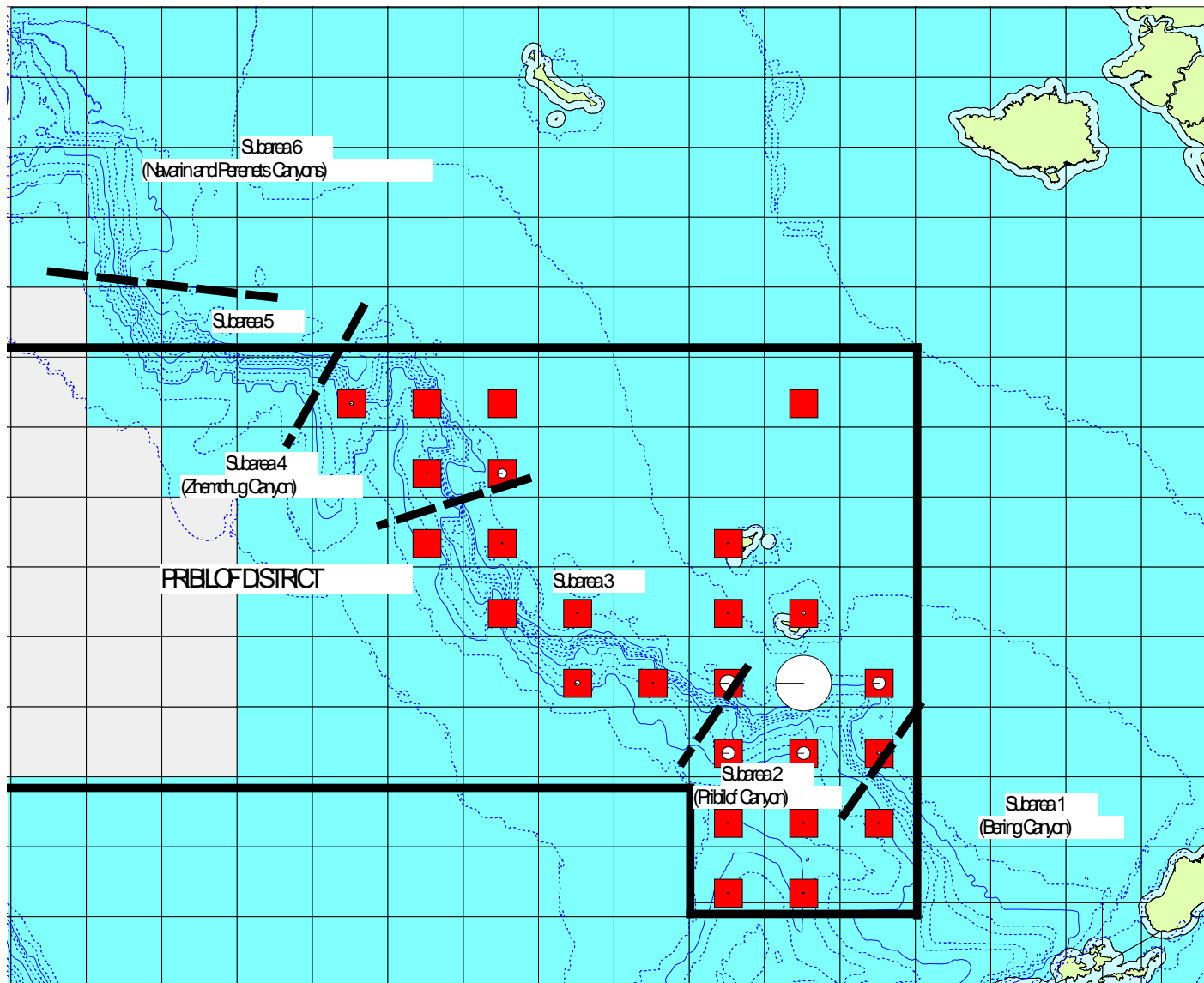
Figure 8. Statistical areas with reported catch during the 1985–2014 Pribilof District golden king crab fisheries: filled red squares denote statistical areas with reported catch; size of overlain white circles are proportional to the percentage of the total 1985–2014 catch reported from statistical area (biggest circle = 68% of total); squares are 1° longitude x 30' latitude State statistical areas.

Table 1a. Commercial fishery history for the Pribilof District golden king crab fishery, 1981/82 through 2016: number of vessels, guideline harvest level (GHL; established in lb, **converted to t**), weight of retained catch (Harvest; t), number of retained crab, pot lifts, fishery catch per unit effort (CPUE; retained crab per pot lift), and average weight (**kg**) of landed crab.

Fishing/Calendar Year	Vessels	GHL	Harvest[a]	Crab[a]	Pot lifts	CPUE	Average weight
1981/82	2	–	CF	CF	CF	CF	CF
1982/83	10	–	32	15,330	5,252	3	2.1
1983/84	50	–	388	253,162	26,035	10	1.5
1984	0	–	0	0	0	–	–
1985	1	–	CF	CF	CF	CF	CF
1986	0	–	0	0	0	–	–
1987	1	–	CF	CF	CF	CF	CF
1988 - 1989	2	–	CF	CF	CF	CF	CF
1990 - 1992	0	–	0	0	0	–	–
1993	5	–	31	17,643	15,395	1	1.7
1994	3	–	40	21,477	1,845	12	1.9
1995	7	–	155	82,489	9,551	9	1.9
1996	6	–	149	91,947	9,952	9	1.6
1997	7	–	81	43,305	4,673	9	1.9
1998	3	–	16	9,205	1,530	6	1.8
1999	3	91	80	44,098	2,995	15	1.8
2000	7	68	58	29,145	5,450	5	2.0
2001	6	68	66	33,723	4,262	8	2.0
2002	8	68	68	34,860	5,279	6	2.0
2003	3	68	**CF**	**CF**	**CF**	**CF**	**CF**
2004	5	68	**CF**	**CF**	**CF**	**CF**	**CF**
2005	4	68	CF	CF	CF	CF	CF
2006 - 2009	0	68	0	0	0	–	–
2010	1	68	CF	CF	CF	CF	CF
2011	2	68	CF	CF	CF	CF	CF
2012	1	68	CF	CF	CF	CF	CF
2013	1	68	CF	CF	CF	CF	CF
2014	1	68	CF	CF	CF	CF	CF
2015	0	59	0	0	0	–	–
2016	0	59	0	0	0	–	–

Note: CF: confidential information due to less than three vessels or processors having participated in fishery; **CF**: confidential information and fishery was closed by emergency order to manage the harvest to the preseason GHL.

[a] Deadloss included.

A. Summary of Major Changes

1. <u>**Changes to the management of the fishery**</u>: Fishery continues to be managed under authority of an ADF&G commissioner's permit; guideline harvest level (GHL) was reduced from 68 t (150,000 lb) to 59 t (130,000 lb) in 2015 to account for bycatch mortality in the directed fishery, non-directed crab fisheries, and groundfish fisheries, and avoid exceeding the ABC. The GHL remained at 59 t (130,000 lb) in 2016 and 2017. The GHL for the 2018 has yet to be established.

2. <u>**Changes to the input data:**</u>
   - Retained catch and discarded catch data have been updated with the results for the 2016 directed fishery, during which no vessels participated, and bycatch in other crab fisheries in 2016, which was zero.
   - Discarded catch estimates from groundfish fisheries have been listed by calendar year from 2009 to 2016, which resulted in 0.24 t of bycatch mortality for 2016.

3. <u>**Changes to the assessment methodology**</u>: This assessment follows the methodology recommended by the CPT since May 2012 and the SSC since June 2012.

4. <u>**Changes to the assessment results, including projected biomass, TAC/GHL, total catch (including discard mortality in all fisheries and retained catch), and OFL**</u>: The computation of OFL in this assessment follows the methodology recommended by the CPT in May 2012 and the SSC in June 2012 applied to the same data and estimates with the same assumptions that were used for estimating the 2013–2017 Tier 5 OFLs; computations applied directly to data and estimates expressed in metric units resulted in minor changes in results due to rounding used in previous assessments.

Table 2. Weight (t) of retained catch and estimated discarded catch of Pribilof golden king crab during crab fisheries, 1993–2016, with total fishery mortality (t) estimated by applying a bycatch mortality rate of 0.2 to the discarded catch in the directed fishery and a bycatch mortality rate of 0.5 to the discarded catch in the non-directed fisheries.

| | | Discarded (no mortality rate applied) | | | |
Calendar Year	Retained	Pribilof Islands golden king crab	Bering Sea snow crab	Bering Sea grooved Tanner crab	Total Mortality
1993	30.60	no data	0.00	no data	—
1994	40.36	no data	3.80	1.15	—
1995	155.09	no data	0.63	15.65	—
1996	149.24	no data	0.24	2.34	—
1997	81.31	no data	4.05	no fishing	—
1998	16.20	no data	33.00	no fishing	—
1999	80.33	no data	0.00	confidential	—
2000	57.70	no data	0.00	confidential	—
2001	66.17	17.82	0.00	confidential	confidential
2002	68.24	19.00	1.06	no fishing	72.57
2003	confidential	confidential	0.15	confidential	72.20
2004	confidential	confidential	0.00	confidential	66.93
2005	confidential	confidential	0.00	confidential	29.85
2006	no fishing	no fishing	0.00	0.00	0.00
2007	no fishing	no fishing	0.00	0.00	0.00
2008	no fishing	no fishing	0.00	no fishing	0.00
2009	no fishing	no fishing	0.96	no fishing	0.48
2010	confidential	confidential	0.00	no fishing	confidential
2011	confidential	confidential	0.27	no fishing	confidential
2012	confidential	confidential	0.27	no fishing	confidential
2013	confidential	confidential	0.58	no fishing	confidential
2014	confidential	confidential	0.12	no fishing	confidential
2015	no fishing	no fishing	0.00	no fishing	0.00
2016	no fishing	no fishing	0.00	no fishing	0.00

Table 3. Estimated annual weight (t) of discarded catch of Pribilof golden king crab (all sizes, males and females) during federal groundfish fisheries by gear type (fixed or trawl) with total bycatch mortality (t) estimated by assuming bycatch mortality rate = 0.5 for fixed-gear fisheries and bycatch mortality rate = 0.8 for trawl fisheries. 1991/92–2008/09 is listed by crab fishery year, while 2009-2016 are listed by calendar year.

Crab fishing year (1991/92–2008/09) or Calendar year (2009-2016)	Bycatch in groundfish fisheries (no mortality rate applied)			Total Mortality
	Fixed	Trawl	Total	
1991/92	0.05	6.11	6.16	4.91
1992/93	3.49	8.87	12.35	8.84
1993/94	0.51	9.64	10.14	7.96
1994/95	0.25	3.22	3.47	2.70
1995/96	0.41	1.90	2.31	1.72
1996/97	0.02	0.87	0.89	0.71
1997/98	1.34	0.49	1.83	1.06
1998/99	6.77	0.18	6.95	3.53
1999/00	4.79	0.65	5.43	2.91
2000/01	1.63	1.88	3.50	2.31
2001/02	1.50	0.36	1.85	1.03
2002/03	0.55	0.21	0.77	0.45
2003/04	0.23	0.18	0.41	0.26
2004/05	0.16	0.39	0.55	0.39
2005/06	0.09	0.06	0.15	0.09
2006/07	1.32	0.12	1.44	0.75
2007/08	8.47	0.16	8.63	4.36
2008/09	3.99	1.56	5.55	3.24
2009	2.67	2.55	5.22	3.38
2010	2.13	1.01	3.14	1.87
2011	0.85	1.33	2.18	1.49
2012	0.73	0.82	1.55	1.02
2013	0.50	2.49	2.99	2.24
2014	0.60	0.53	1.13	0.73
2015	0.81	1.89	2.70	1.92
2016	0.23	0.16	0.39	0.24
Average	1.70	1.83	3.53	2.31

Table 4. Retained-catch weights (t) and estimates of discarded catch weights (t) of Pribilof Islands golden king crab available for a Tier 5 assessment; shaded, bold values are used in computation of the recommended (status quo Alternative 1) Tier 5 OFL.

| | | Retained catch weight | Discarded catch weight (estimated) | | | |
| | | Fish tickets | Observer data: lengths, catch per sampled pot | | Blend method: Catch Accounting System | |
Calendar Year[a]	Crab Fishing Year[b]	Directed fishery	Directed fishery	Non-directed crab fisheries	Fixed gear, groundfish	Trawl gear, groundfish
	1981/82	Confidential				
	1982/83	31.74				
	1983/84	388.49				
1984	1984/85	0.00				
1985	1985/86	Confidential				
1986	1986/87	0.00				
1987	1987/88	Confidential				
1988	1988/89	Confidential				
1989	1989/90	Confidential				
1990	1990/91	0.00				
1991	1991/92	0.00			0.05	6.11
1992	1992/93	0.00			**3.49**	**8.87**
1993	1993/94	**30.60**			**0.51**	**9.64**
1994	1994/95	**40.36**		**4.95**	**0.25**	**3.22**
1995	1995/96	**155.09**		**16.28**	**0.41**	**1.90**
1996	1996/97	**149.24**		**2.58**	**0.02**	**0.87**
1997	1997/98	**81.31**		**4.05**	**1.34**	**0.49**
1998	1998/99	**16.20**		**33.00**	**6.77**	**0.18**
1999	1999/00	80.33		Confidential	4.79	0.65
2000	2000/01	57.70		Confidential	1.63	1.88
2001	2001/02	**66.17**	**17.20**	Confidential	1.50	0.36
2002	2002/03	**68.24**	**19.00**	1.06	0.55	0.21
2003	2003/04	**Confidential**	**Confidential**	Confidential	0.23	0.18
2004	2004/05	**Confidential**	**Confidential**	Confidential	0.16	0.39
2005	2005/06	**Confidential**	**Confidential**	Confidential	0.09	0.06
2006	2006/07	0.00	0.00	0.00	1.32	0.12
2007	2007/08	0.00	0.00	0.00	8.47	0.16
2008	2008/09	0.00	0.00	0.00	3.99	1.56
2009	2009/10	0.00	0.96	0.96	2.67	2.55
2010	2010/11	**Confidential**	**Confidential**	0.00	2.13	1.01
2011	2011/12	Confidential	Confidential	0.27	0.85	1.33
2012	2012/13	Confidential	Confidential	0.27	0.73	0.82
2013	2013/14	Confidential	Confidential	0.58	0.50	2.49
2014	2014/15	Confidential	Confidential	0.12	0.60	0.53
2015	2015/16	0.00	0.00	0.00	0.812	1.890
2016	2016/17	0.00	0.00	0.00	0.231	0.158

[a] Year convention for retained weights in directed fishery, 1984-2016, estimates of discarded bycatch weights in directed, non-directed crab fisheries, and grounfish (2009-2016).

[b] Year convention for retained weights in directed fishery, 1981/82-1983/84, and estimates of discarded bycatch rates in groundfish fisheries (1991/92-2008/09).

The recommended OFL is set as a total-catch OFL using 1993–1998 to compute average annual retained catch, an estimate of the ratio of bycatch mortality to retained catch during the directed fishery, an estimate of the average annual bycatch mortality due to the non-directed crab fisheries during 1994–1998, and an estimate of average annual bycatch mortality due to the groundfish fisheries during 1992/93–1998/99; i.e.,

$$OFL_{2018} = (1+R_{2001-2010})*RET_{1993-1998} + BM_{NC,1994-1998} + BM_{GF,92/93-98/99},$$

where,

- $R_{2001-2010}$ is the average of the estimated annual ratio of bycatch mortality to retained catch in the directed fishery during 2001–2010
- $RET_{1993-1998}$ is the average annual retained catch in the directed crab fishery during 1993–1998
- $BM_{NC,1994-1998}$ is the estimated average annual bycatch mortality in non-directed crab fisheries during 1994–1998
- $BM_{GF,92/93-98/99}$ is the estimated average annual bycatch mortality in groundfish fisheries during 1992/93–1998/99.

Statistics on the data and estimates used to calculate $RET_{1993-1998}$, $R_{2001-2010}$, $BM_{NC,1994-1998}$, and $BM_{GF,93/94-98/99}$ are provided in Table 5; the column means in Table 5 are the calculated values of $RET_{1993-1998}$, $R_{2001-2010}$, $BM_{NC,1994-1998}$, and $BM_{GF,93/94-98/99}$. Using the calculated values of $RET_{1993-1998}$, $R_{2001-2010}$, $BM_{NC,1994-1998}$, and $BM_{GF,93/94-98/99}$, the calculated value of OFL_{2018} is,

$$OFL_{2018} = (1+0.052)*78.80 \text{ t} + 6.09 \text{ t} + 3.79 \text{ t} = 93 \text{ t (204,527 lbs)}.$$

Author recommended ABC. 25% buffer on OFL; i.e., ABC = (1-0.25)·(93 t) = 70 t (153,395 lb).

Table 5. Data for calculation of $RET_{1993-1998}$ (t) and estimates used in calculation of $R_{2001-2010}$ (ratio, t:t), $BM_{NC,1994-1998}$ (t), and $BM_{GF,92/93-98/99}$ (t) for calculation of the recommended (status quo Alternative 1) Pribilof Islands golden king crab Tier 5 2018 OFL (t); values under $RET_{1993-1998}$ are from Table 1, values under $R_{2001-2010}$ were computed from the retained catch data and the directed fishery discarded catch estimates in Table 2 (assumed bycatch mortality rate = 0.2), values under $BM_{NC,1994-1998}$ were computed from the non-directed crab fishery discarded catch estimates in Table 2 (assumed bycatch mortality rate = 0.5) and values under $BM_{GF,92/93-98/99}$ are from Table 3.

Calendar Year[a]	Crab Fishing Year[b]	$RET_{1993-1998}$	$R_{2001-2010}$	$BM_{NC,1994-1998}$	$BM_{GF,92/93-98/99}$
1993	1992/93	30.60			8.84
1994	1993/94	40.36		2.48	7.96
1995	1994/95	155.09		8.14	2.70
1996	1995/96	149.24		1.29	1.72
1997	1996/97	81.31		2.03	0.71
1998	1997/98	16.20		16.50	1.06
1999	1998/99				3.53
2000	1999/00				
2001	2000/01		0.054		
2002	2001/02		0.056		
2003	2002/03		conf.		
2004	2003/04		conf.		
2005	2004/05		conf.		
2006	2005/06				
2007	2006/07				
2008	2007/08				
2009	2008/09				
2010	2009/10		conf.		
	N	6	6	5	7
	Mean	78.80	0.052	6.09	3.79
	S.E.M	24.84	0.004	2.87	1.25
	CV	0.32	0.07	0.47	0.33

[a.] Year convention corresponding with values under $RET_{1993-1998}$, $R_{2001-2010}$, and $BM_{NC,1994-1998}$.

[b.] Year convention corresponding with values under $BM_{GF,92/93-98/99}$.

NMFS EBS slope survey

- Interest by CPT and SSC in using biennial Bering Sea upper continental slope survey data to establish annual OFL/ABC on the basis of biomass estimates as an alternative to the Tier 5 approach

- Only post-2000 data used because of differences in sampling gear, survey design, sampling methodology, and species identification in 1979-91 and 2000 surveys

- Total biomass (males and females) available starting in 2002, BUT mature and legal area-swept biomass estimates only available starting in 2008

Biomass estimates

- Maturity: 107 mm CL (Somerton and Otto 1986)

- Legal size: 124 mm CL (proxy for 5.5 in CW)

- Weight (g) = $(0.0002988)x(CL)^{3.135}$

An area-swept estimate of biomass and of the variance of the biomass estimate was computed for each stratum within a survey subarea and summed over strata within the subarea to obtain area-swept estimates of biomass within a subarea and of the variance of that biomass estimate; estimates of the biomass and of variances of estimates within subareas were summed over subareas to obtain estimates of biomass in aggregates of subareas and of the variances of those estimates.
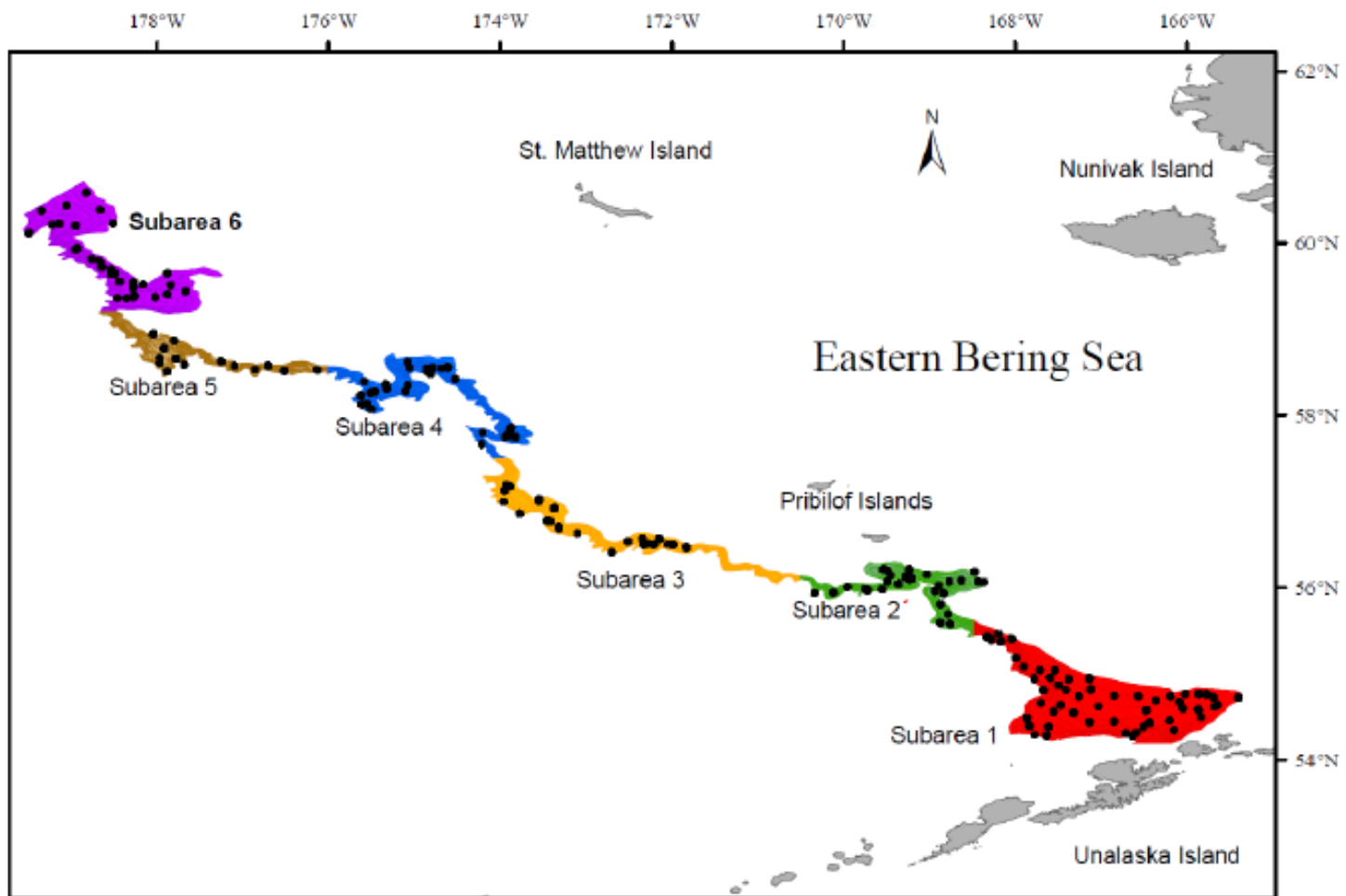
Figure 2. Map of standard survey area and the six subareas. Indicated are the 175 successful trawl stations (black dots) completed during the 2016 EBSS survey (taken form Hoff 2016).

Subarea 6
(Navarin and Pervenets Canyons)

Subarea 5

Subarea 4
(Zhemchug Canyon)

PRIBILOF DISTRICT

Subarea 3

Subarea 2
(Pribilof Canyon)

Subarea 1
(Bering Canyon)

2008 GKC CPUE (kg/km²)

1,000
100
10

★ CPUE>1000
● No GKC

Subarea 6
(Navarin and Pervenets Canyons)

Subarea 5

Subarea 4
(Zhemchug Canyon)

PRIBILOF DISTRICT

Subarea 3

Subarea 2
(Pribilof Canyon)

Subarea 1
(Bering Canyon)

2010 GKC CPUE (kg/km²)

— 1,000
— 100
— 10

★ CPUE>1000
● No GKC

Population and fishery distribution

- Survey distribution and fishery catch and effort distribution concentrated in the Prib Canyon area (survey subarea 2).

- GKC sporadically distributed in survey subareas 3 and 4 with some limited catch and effort in those areas.

- Portions of survey subareas 1 and 5 in the Prib Dist largely devoid of GKC.

- GKC in survey subarea 6 exploited by St Matts section fishery when prosecuted.

Random Effects Model: Program "re.exe"

- Considers the process errors as "random effects" (i.e., drawn from an underlying distribution) and integrated out of the likelihood.

- Developed by the NPFMC groundfish plan team's survey averaging working group as a smoothing technique similar to the Kalman Filter

  – Provides more flexibility with non-linear processes and non-normal error structures.
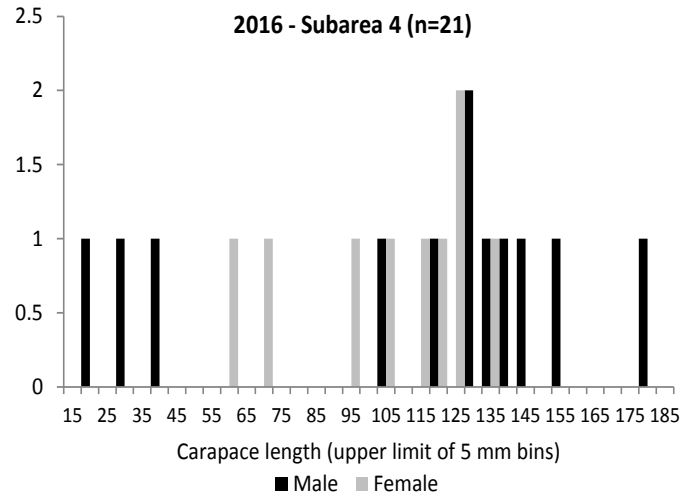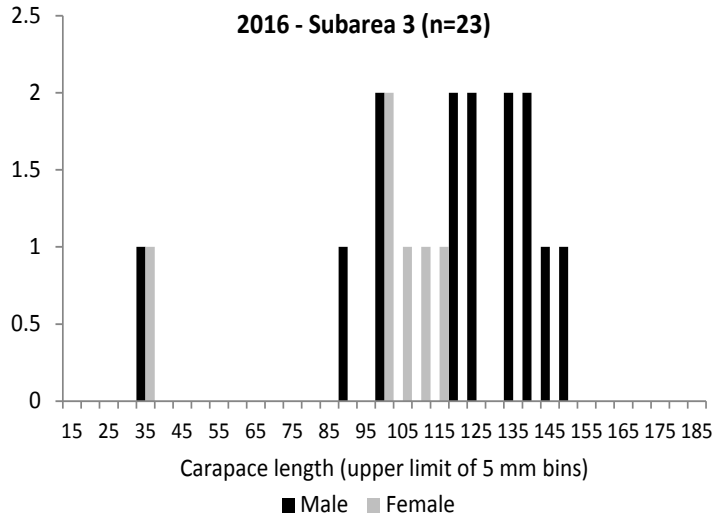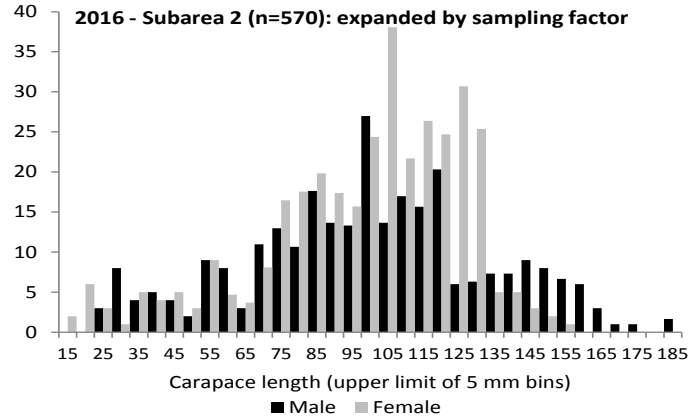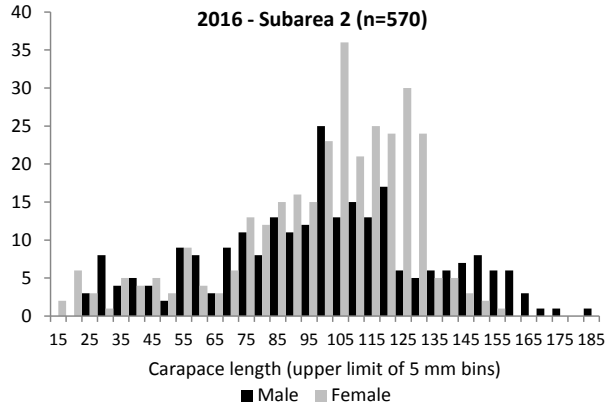
Model results
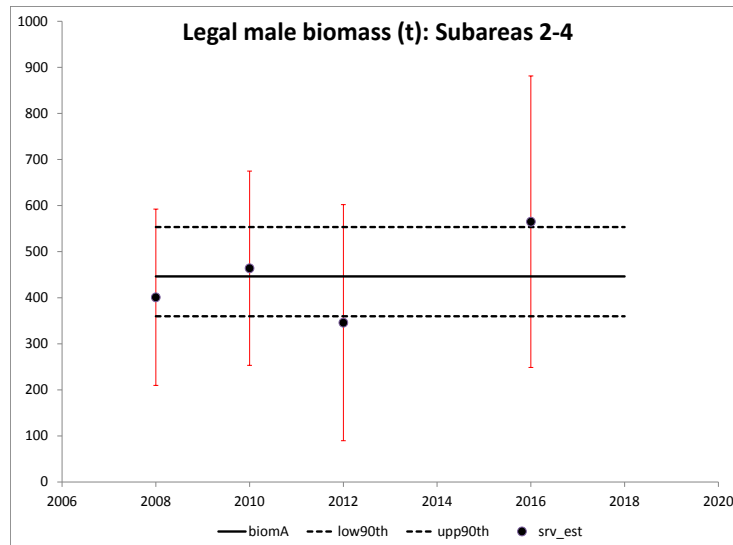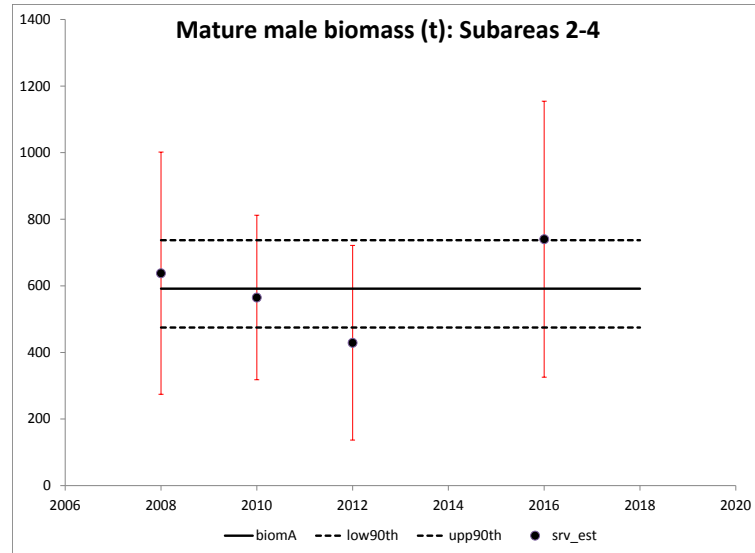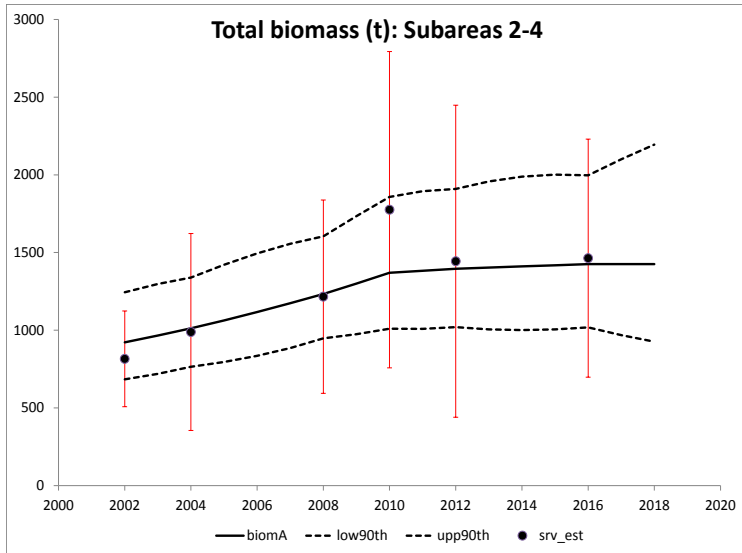
2016 Slope Survey
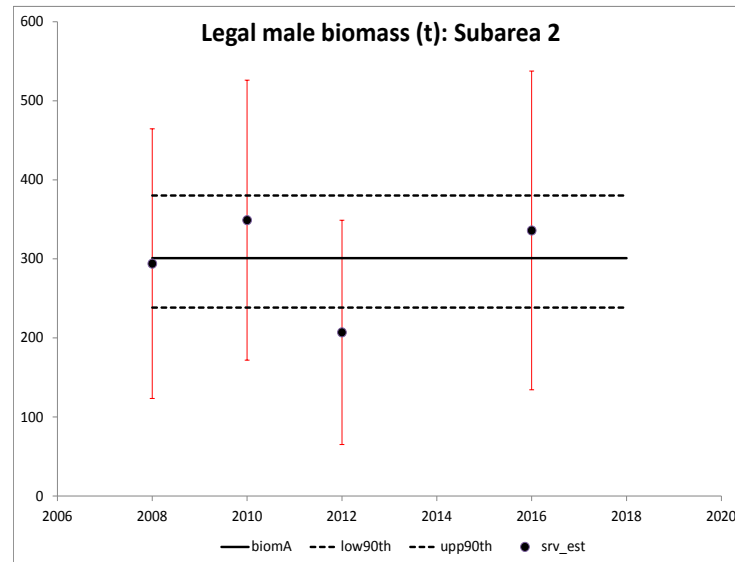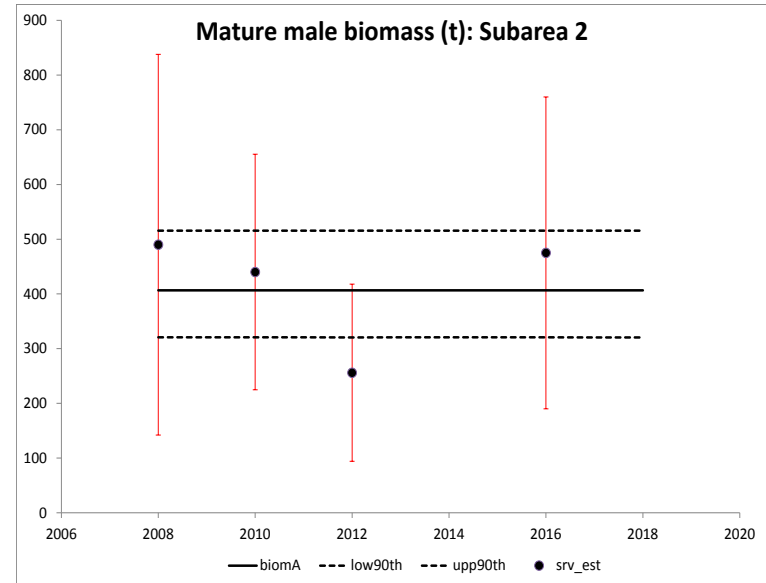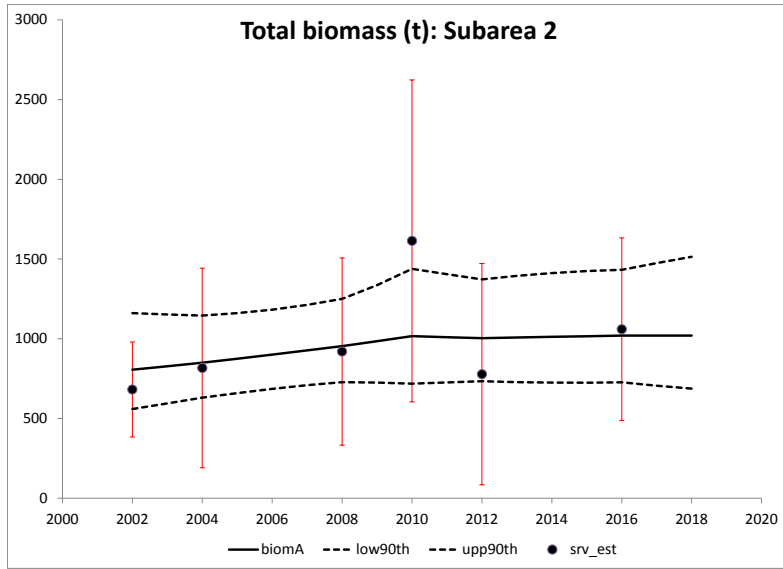
2016 Slope Survey

Model Performance and tier recommendation

Tier 4 description from SAFE:

"*Tier 4 is for stocks where essential life-history, recruitment information, and understanding are insufficient to achieve Tier 3. Therefore, it is not possible to estimate the spawner-recruit relationship. **However, there is <u>sufficient information for simulation modeling that captures the essential population dynamics</u> of the stock as well as the performance of the fisheries.*"

Author recommendation: Keep PIGKC as a tier 5 stock

Guidance from CPT?

- Do the results meet the Tier 4 criterion of having sufficient information for simulation modeling that captures the essential population dynamics of the stock?
- Estimate process error?