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# Pribilof Islands Blue King Crab

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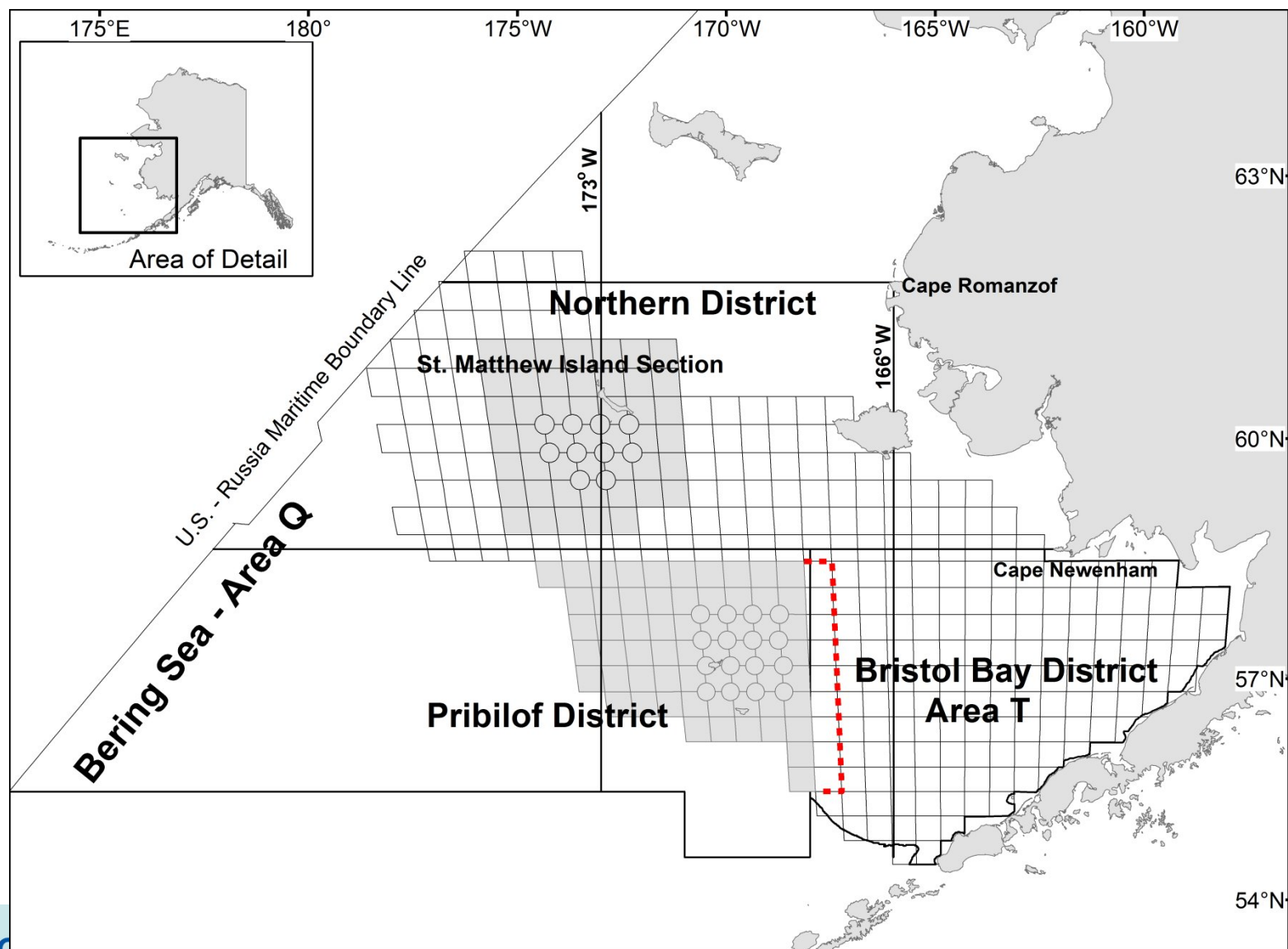


NOAA FISHERIES

# Changes From 2014 Assessment

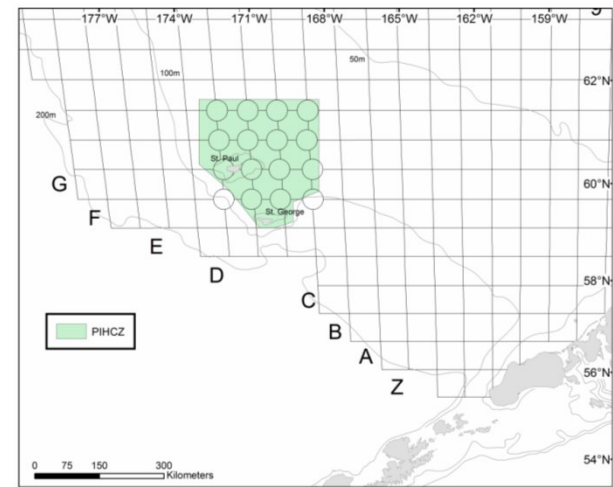
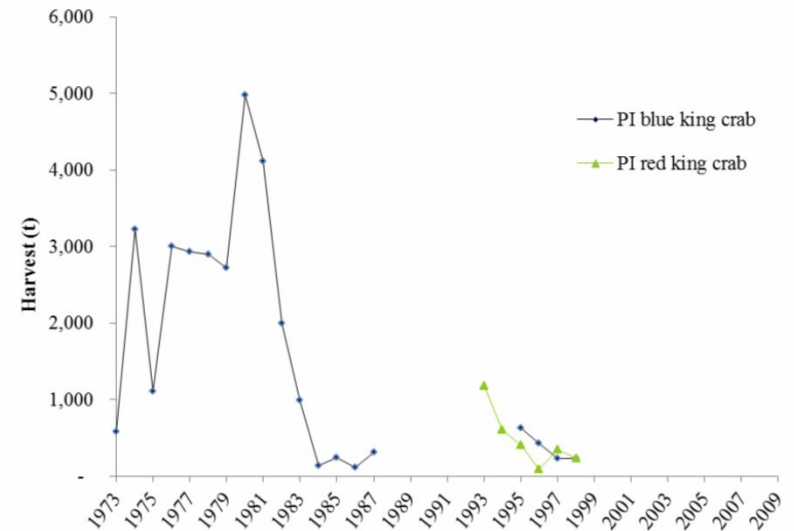
- Same approach to OFL
  - Tier 4 status determination
  - Tier 5 OFL, ABC
- New survey smoothing method for survey MMB
  - Old: 3-year inverse-variance running average
  - New: Random effects/Kalman filter
- New Fishery Data for 2014/15
  - directed fishery
    - no catch
  - crab fishery bycatch
    - no catch
  - groundfish fisheries
    - 2013/14 updated
    - 2014/15 new
- New trawl survey data
  - new standardized dataset
  - abundance, biomass
  - size compositions by sex, shell condition, maturity

# Management Area & Stock Definition



# Management Performance

- Overfishing not occurring
- Stock is overfished
  - PIHCA closed to trawling in 1994
  - directed fishery closed in 1999
  - declared overfished 2002
  - rebuilding plan implemented 2004
  - 2009: NMFS determined it will not rebuild by 2014
  - 2014: Final EA for Amendments 43, 103 released
  - 2015: Secretary approves revised rebuilding plan
    - PIHCZ closed to P. cod pot fishing
    - rebuilding may occur w/in 50 years

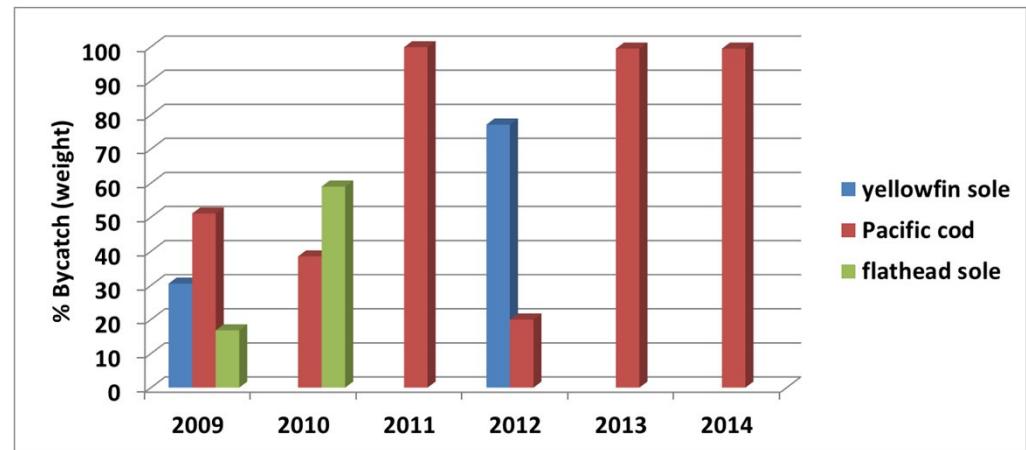
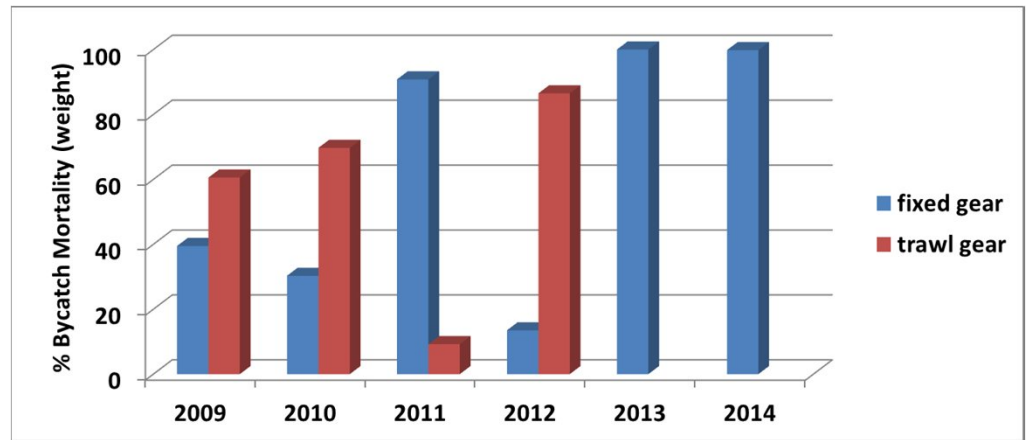
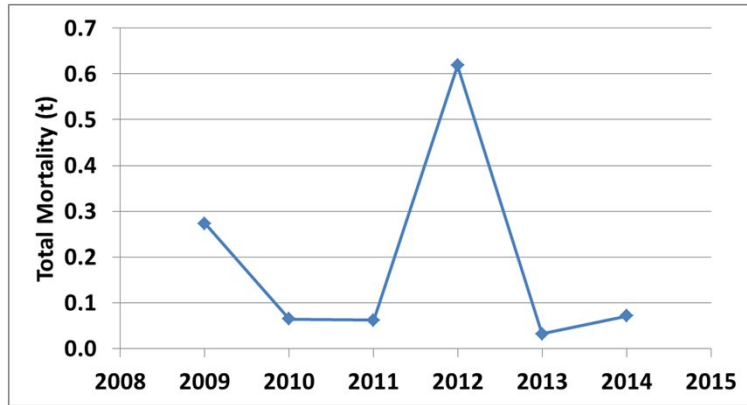


# Catch History

Year	Crab pot fisheries			Groundfish fisheries	
	Non-retained legal male	Sublegal male	Female	Fixed gear	Trawl gear
	(t)	(t)	(t)	(t)	(t)
1991/1992	NA	NA	NA	0.03	4.96
1992/1993	NA	NA	NA	0.44	48.63
1993/1994	NA	NA	NA	0.00	27.39
1994/1995	NA	NA	NA	0.02	5.48
1995/1996	NA	NA	NA	0.05	1.03
1996/1997	0	0.4	0	0.02	0.05
1997/1998	0	0	0	0.73	0.10
1998/1999	1.15	0.23	1.86	9.90	0.06
1999/2000	1.75	2.15	0.99	0.40	0.02
2000/2001	0	0	0	0.06	0.02
2001/2002	0	0	0	0.42	0.02
2002/2003	0	0	0	0.04	0.24
2003/2004	0	0	0	0.17	0.18
2004/2005	0	0	0	0.41	0.00
2005/2006	0	0	--	0.18	1.07
2006/2007	0	0	--	0.07	0.06
2007/2008	0	0	--	2.00	0.11
2008/2009	0	0	--	0.07	0.38
2009/2010	0	0	--	0.11	0.17
2010/2011	0	0.09	--	0.02	0.05
2011/2012	0	0	--	0.06	0.01
2012/2013	0	0	0	0.08	0.54
2013/2014	0	0	0	0.03	0.00
2014/2015	0	0	0	0.07	0.00



# Recent bycatch in the groundfish fisheries



# Trawl Survey Results

## 2015 Survey

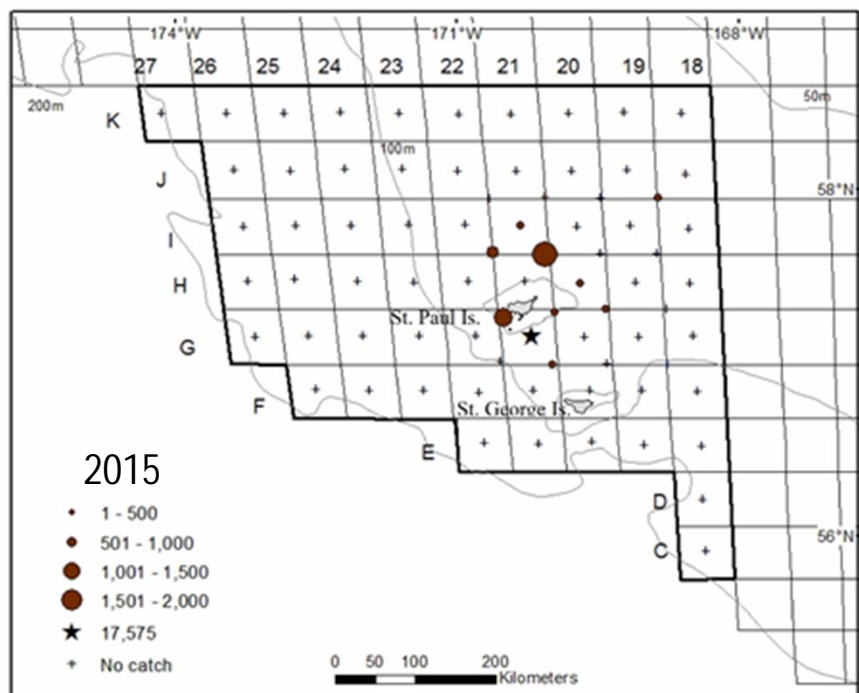
Stock Component	Number of tows in District	Tows with crab	Number of crab measured	Number of crab caught	Abundance (millions)		Biomass (mt)	
					estimate	95% CI	estimate	95% CI
Immature male	86	2	4	4	0.076	0.113	82	120
Mature male	86	8	13	13	0.234	0.168	622	480
Legal male	86	5	7	7	0.125	0.109	428	385
Immature female	86	0	0	0	0.000	0.000	0	0
Mature female	86	4	11	11	0.202	0.260	160	207

## 2014 Survey

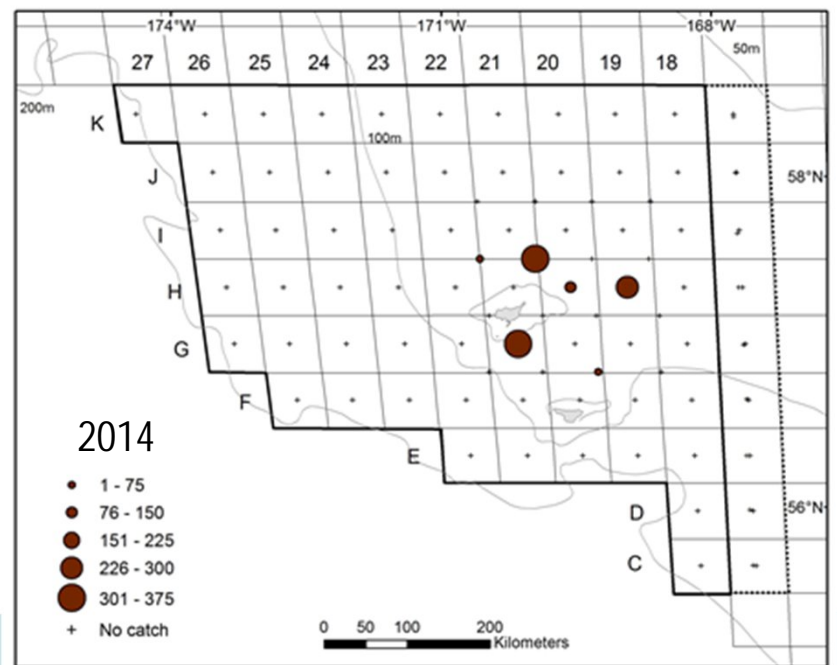
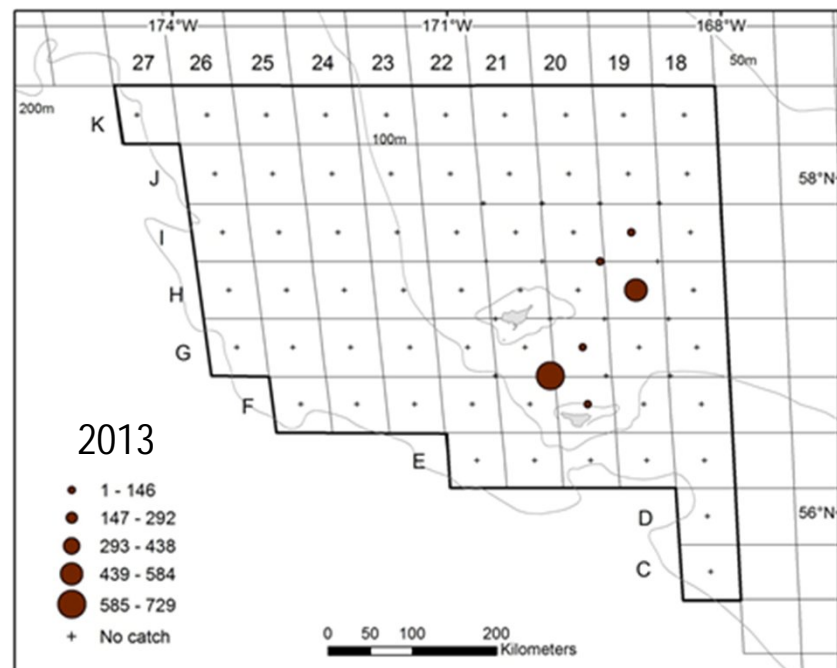
Stock Component	Number of tows in District	Tows with crab	Number of crab measured	Number of crab caught	Abundance (millions)		Biomass (mt)	
					estimate	95% CI	estimate	95% CI
Immature male	86	3	5	5	0.091	0.105	83	102
Mature male	86	2	5	5	0.092	0.128	233	320
Legal male	86	2	5	5	0.092	0.128	233	320
Immature female	86	1	1	1	0.028	0.054	16	32
Mature female	86	3	4	4	0.074	0.088	91	108



# Survey Densities: All Crab

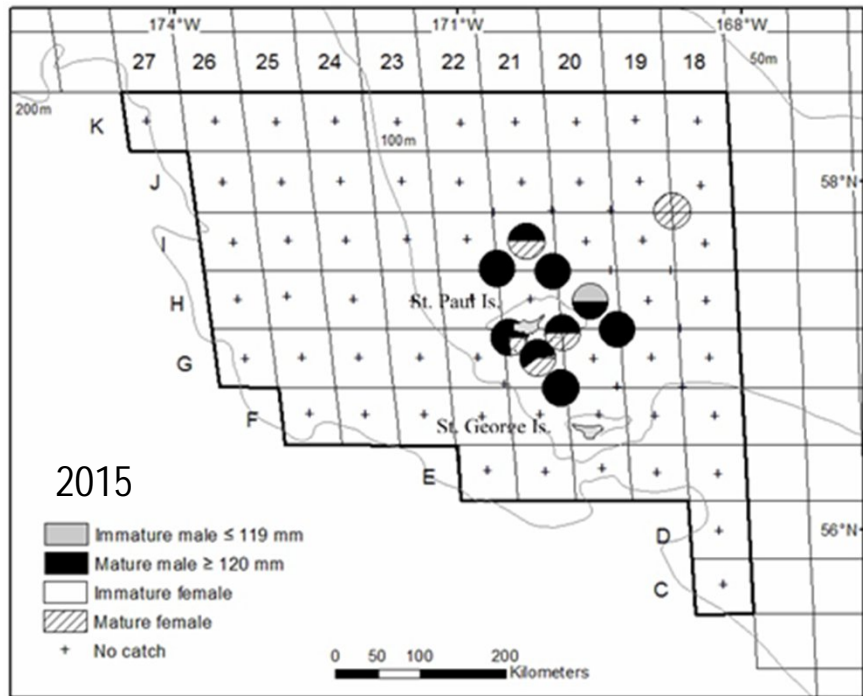


- in number/nm<sup>2</sup>

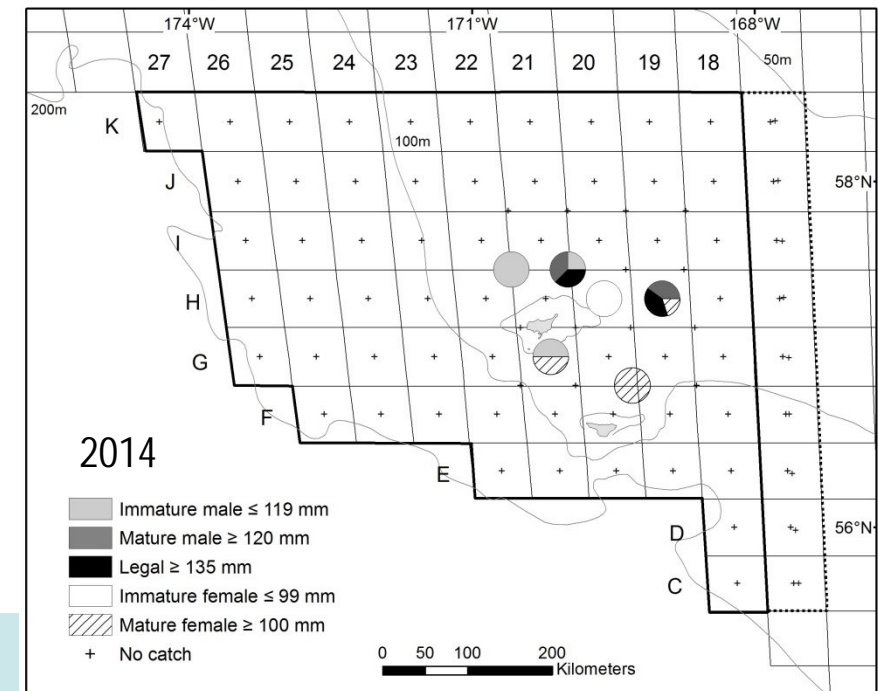
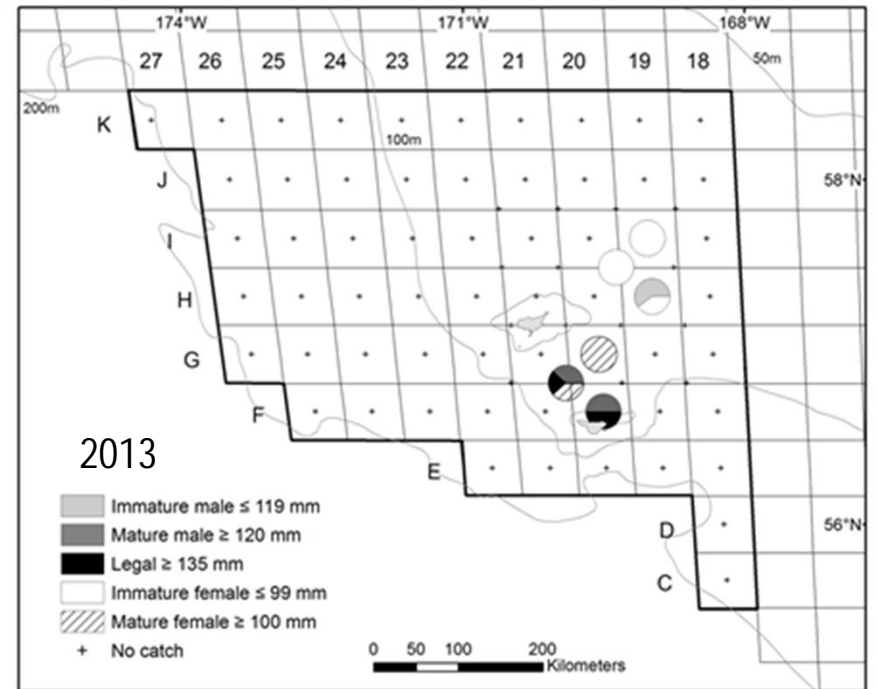




# Survey Size Classes

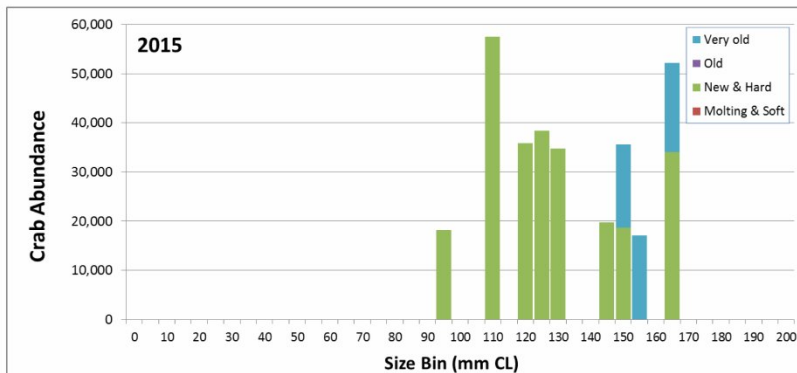
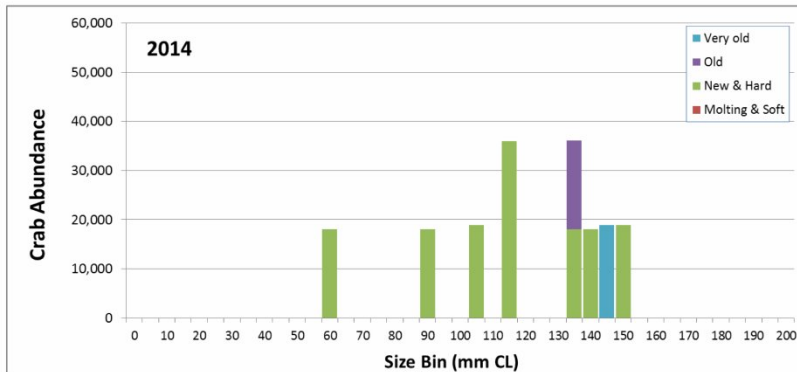
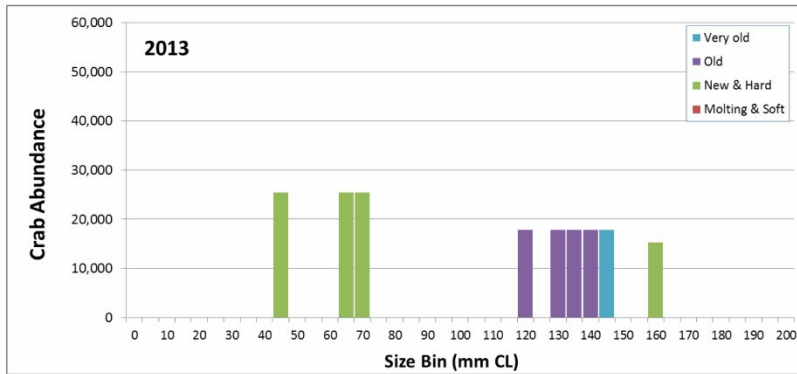


- in number/nm<sup>2</sup>

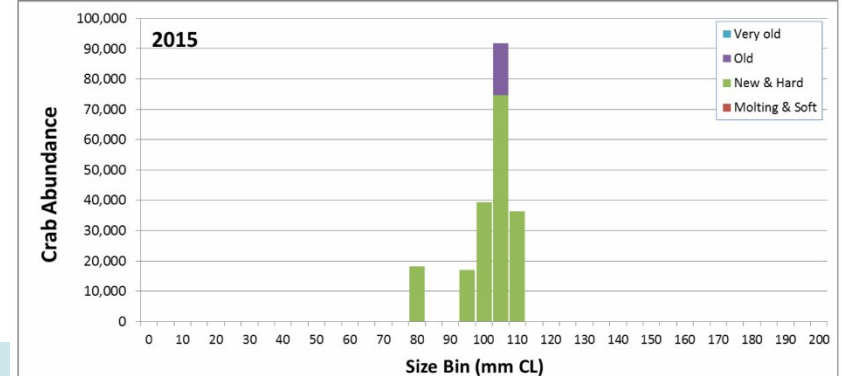
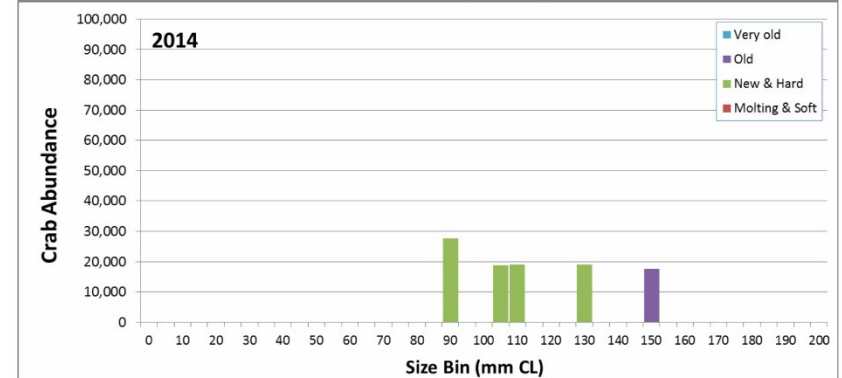
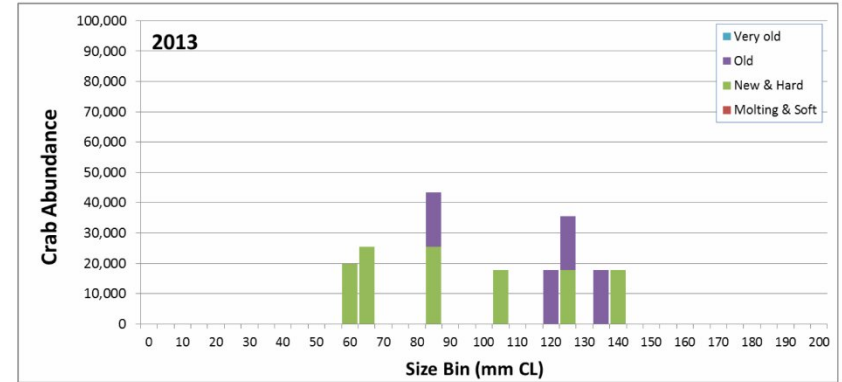


# Size compositions

## Males

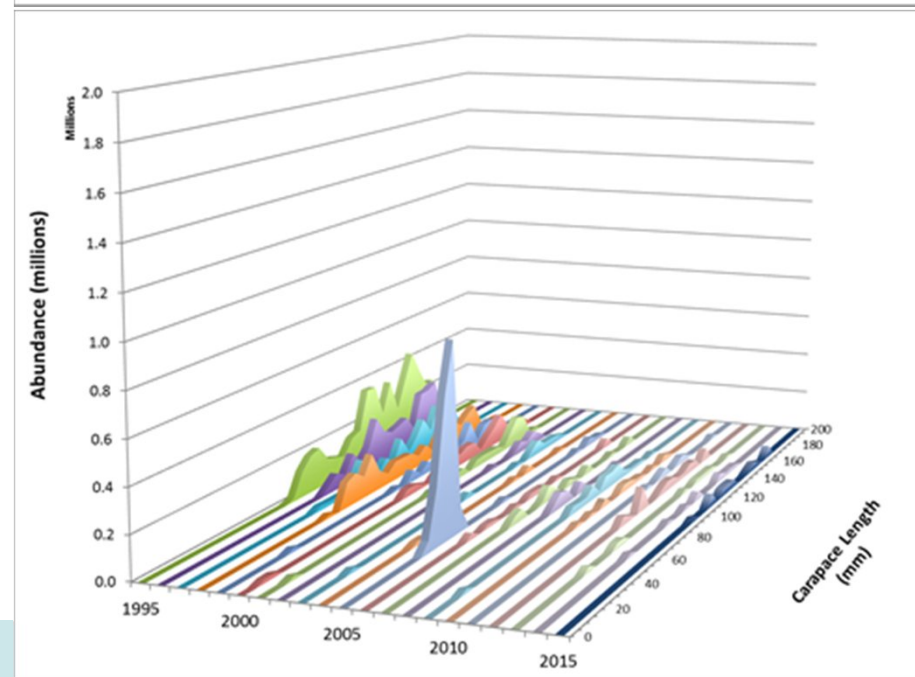
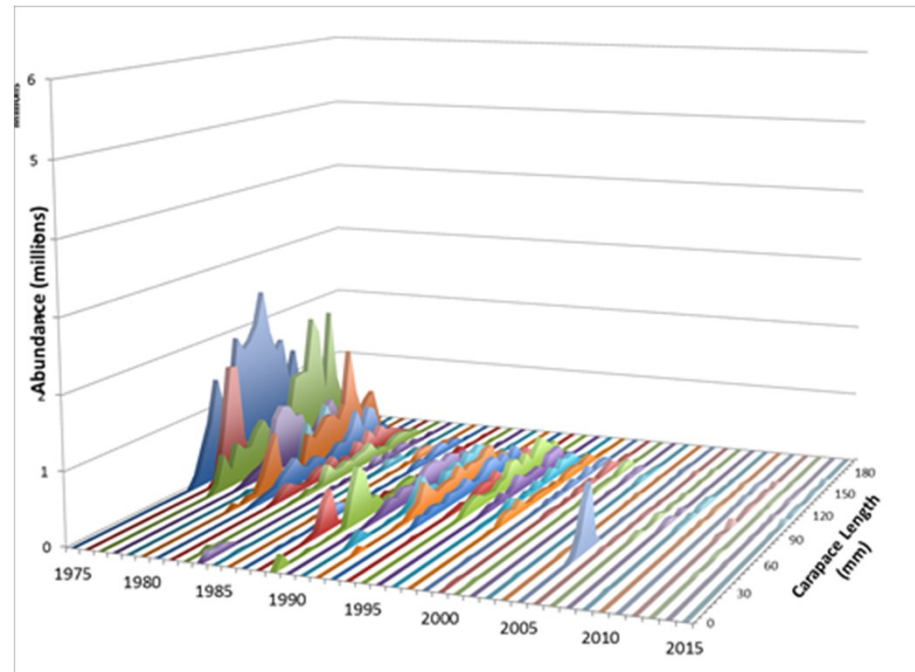


## Females



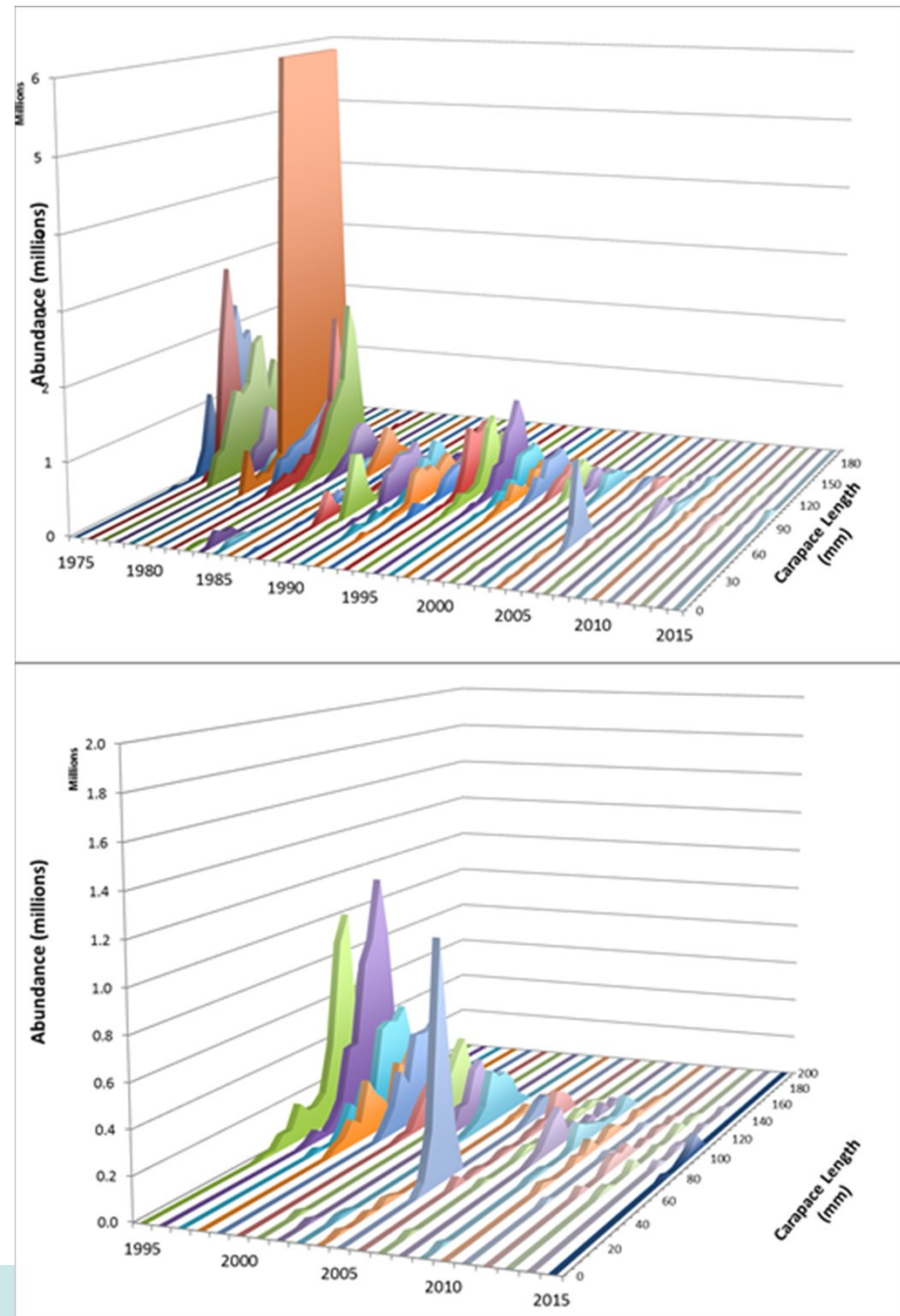
# Trawl Survey Trends

- New standardization
- Males



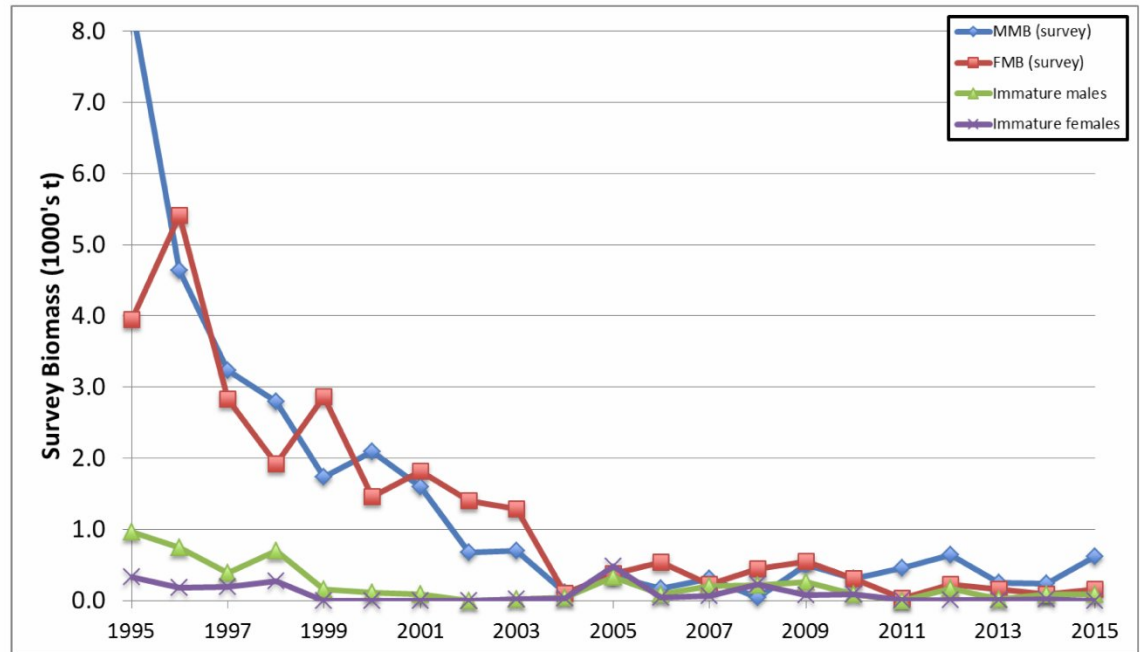
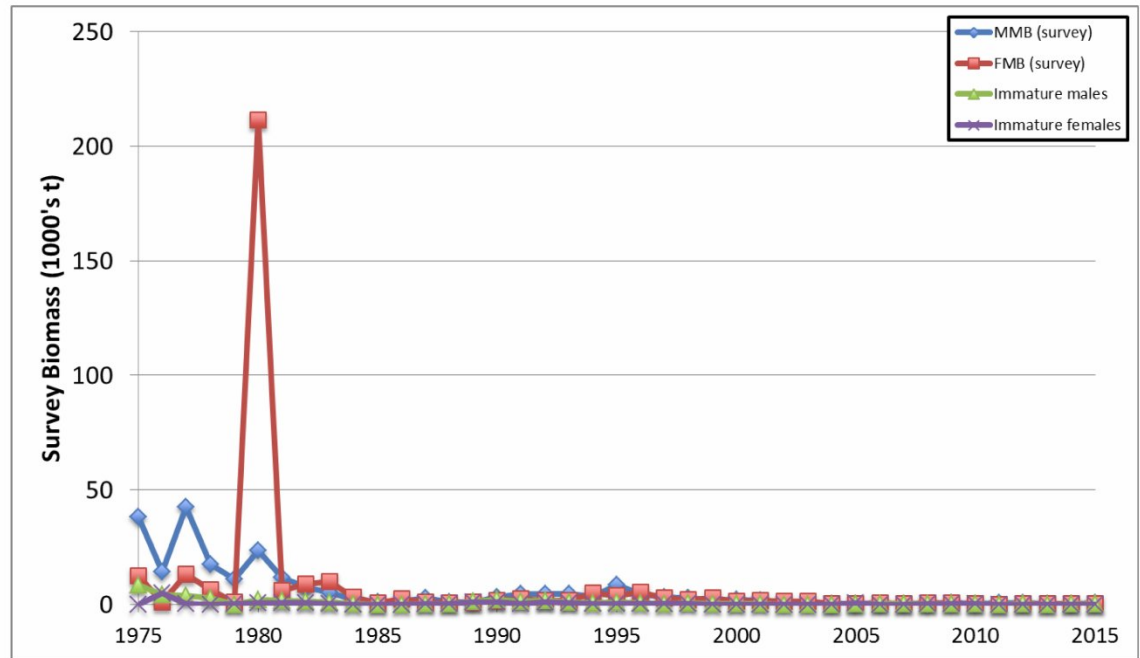
# Trawl Survey Trends

- New standardization
- Females

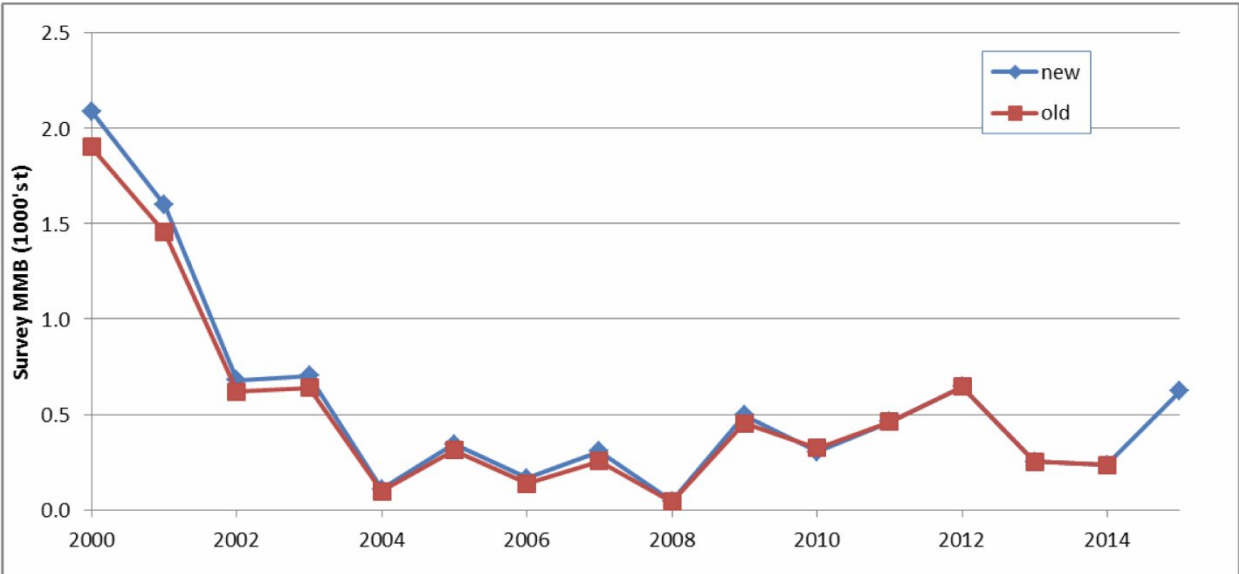
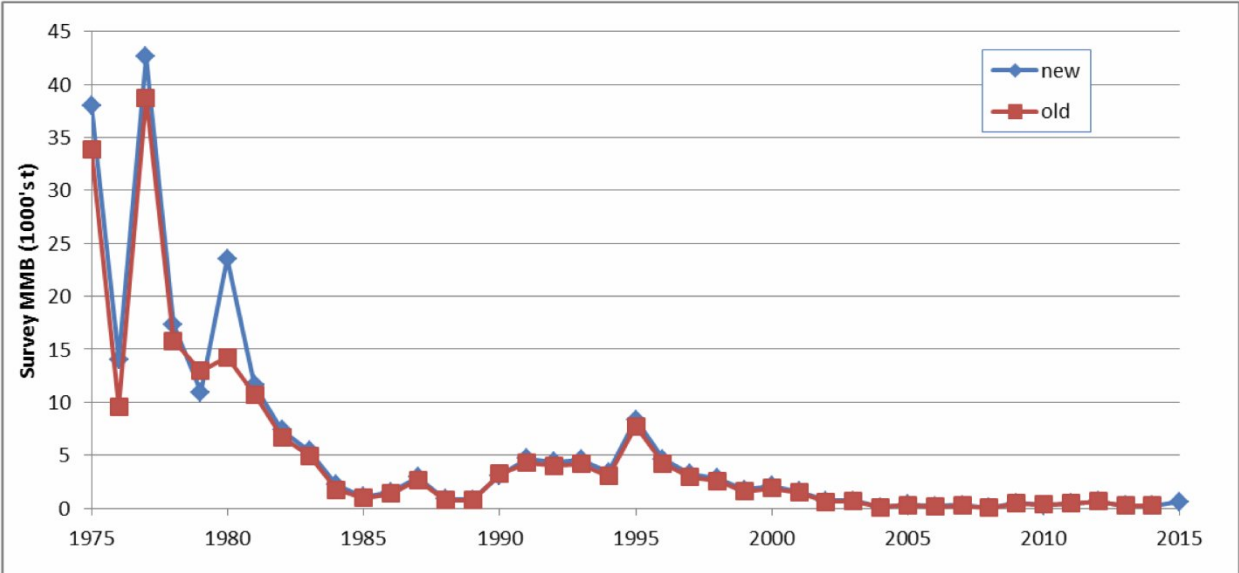


# Trawl Survey Trends

- New standardization



# Trawl Survey Trends: New vs. Old Datasets



## Tier 4 Overfished Status Determination

- Raw Data
- IV: inverse variance averaging
- RE: Random Effects model

- $B_{MSY}$  (proxy) is average MMB-at-mating over 1980-84 and 1990-97

$$MMB_{fy} = MMB_{Sy} \cdot e^{-M \cdot t_{sf}}$$

at fishing

$$MMB_{my} = [MMB_{fy} - RM_y - DM_y] \cdot e^{-M \cdot t_{fm}}$$

at mating

- "Current" B is MMB-at-mating for assessment year
  - uses smoothed estimate of  $MMB_{Sy}$  in assessment year
  - 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:
    - $MMB_f = MMB_S \cdot e^{-M \cdot t_{sf}}$
    - $RM_{OFL} = (1 - e^{-F_{OFL}}) \cdot MMB_S \cdot e^{-M \cdot t_{sf}}$
    - $DM_{OFL} = \theta \cdot \frac{MMB_f}{p_{male}}$
    - $OFL = RM_{OFL} + DM_{OFL}$
  - 3. project MMB-at-mating from the "current" survey MMB and the OFL.
  - 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.



## Averaging methods

- Raw Data
- IV: inverse variance averaging

$$\langle MMB_s \rangle_y = \frac{[\sum_{-1 \leq i \leq 1} w_{y+i} \cdot MMB_{s_{y+i}}]}{\sum_{-1 \leq i \leq 1} w_{y+i}} \quad ; w_y = \frac{1}{\sigma_{s_y}^2}$$

- RE: Random Effects model

$$\langle \ln(MMB_s) \rangle_y = \langle \ln(MMB_s) \rangle_{y-1} + \varepsilon_y, \text{ where } \varepsilon_y \sim N(0, \phi^2)$$

$$\ln(MMB_{s_y}) = \langle \ln(MMB_s) \rangle_y + \eta_y, \quad \text{where } \eta_y \sim N(0, \sigma_{s_y}^2)$$

State Eq.

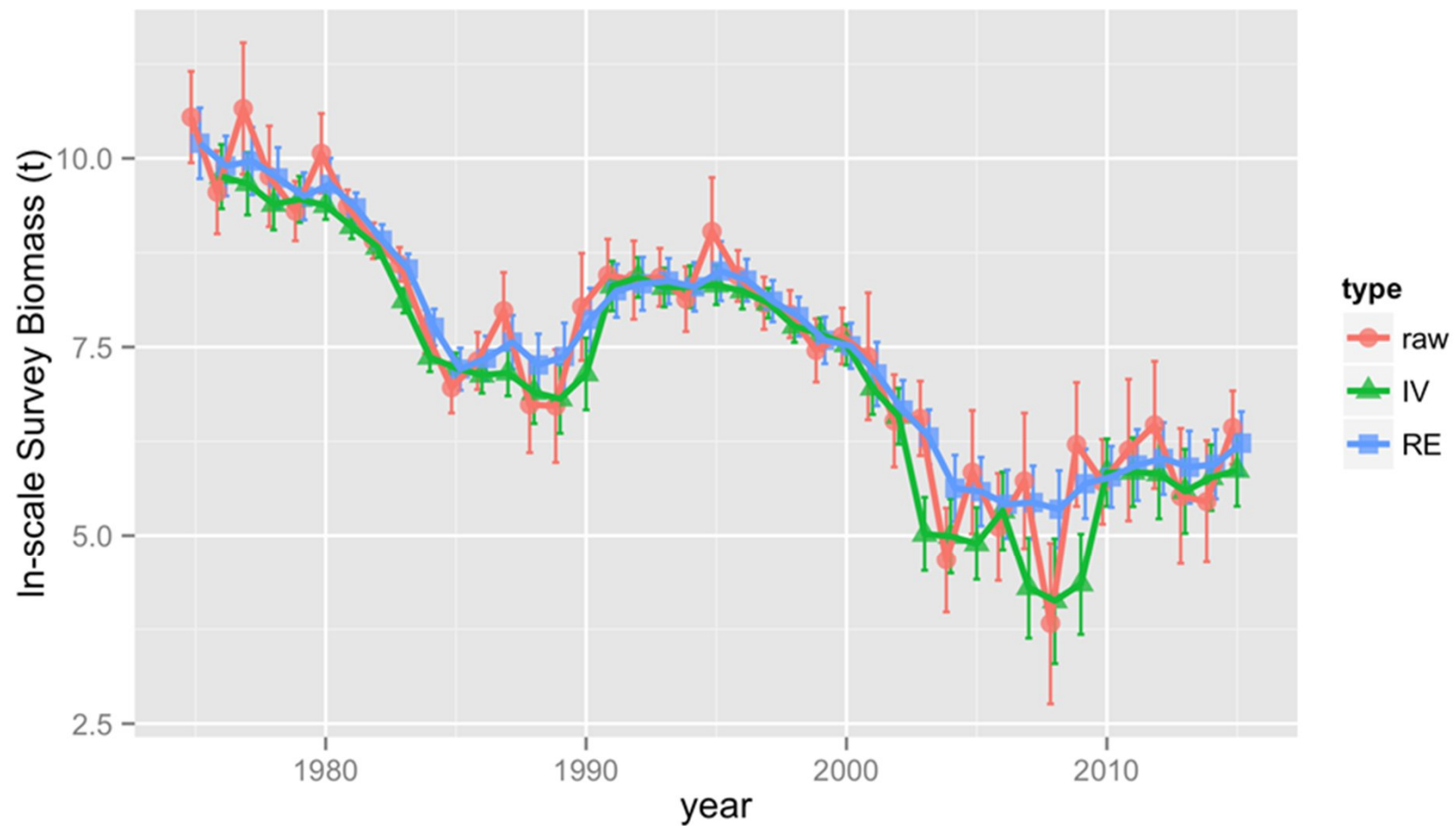
Observation Eq.

$$\Lambda = \sum_y \left[ \ln(2\pi\phi) + \left( \frac{\langle \ln(MMB_s) \rangle_y - \langle \ln(MMB_s) \rangle_{y-1}}{\phi} \right)^2 \right] + \sum_y \left( \frac{\ln(MMB_{s_y}) - \langle \ln(MMB_s) \rangle_y}{\sigma_{s_y}} \right)^2$$

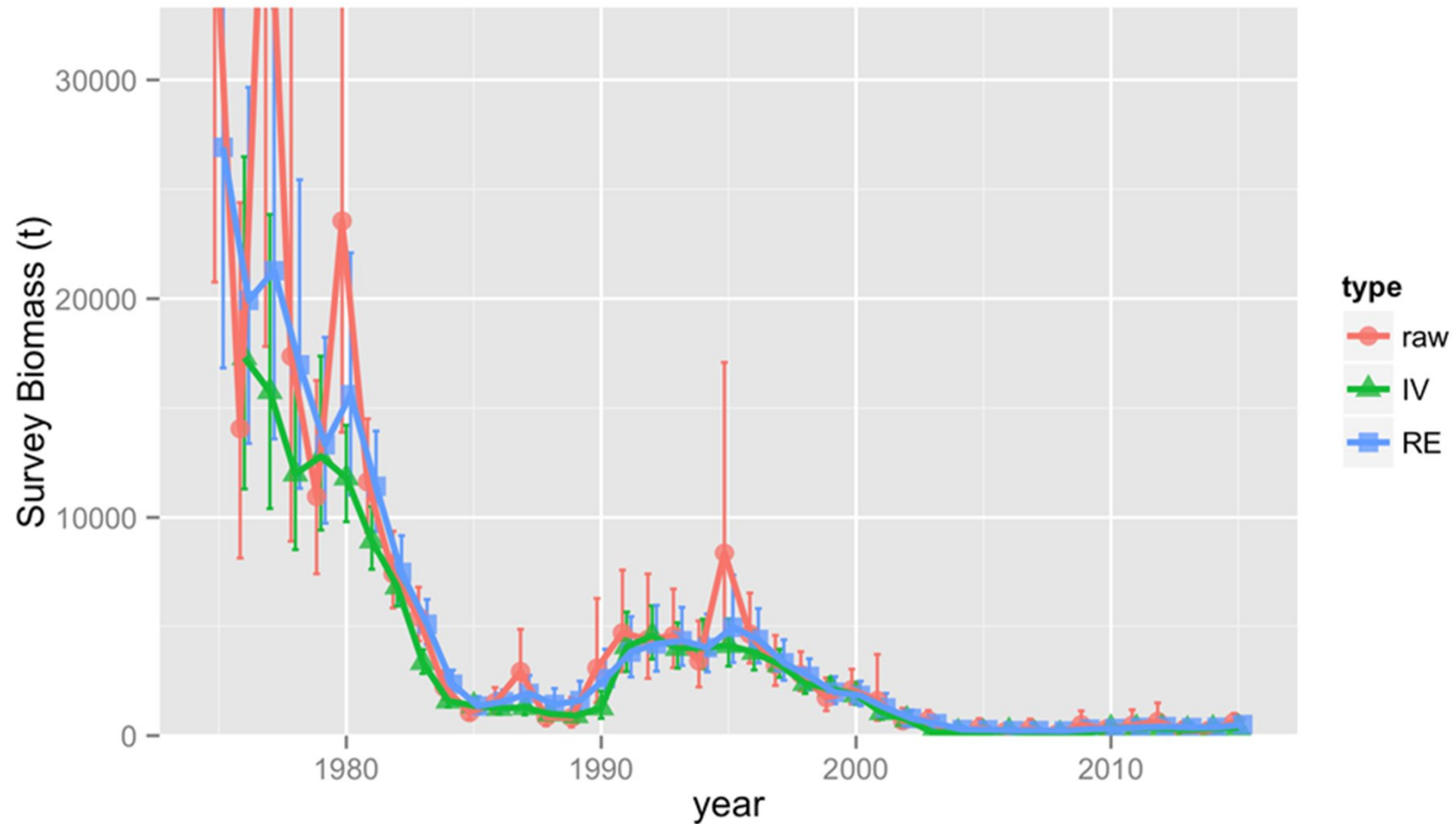
Objective  
Function



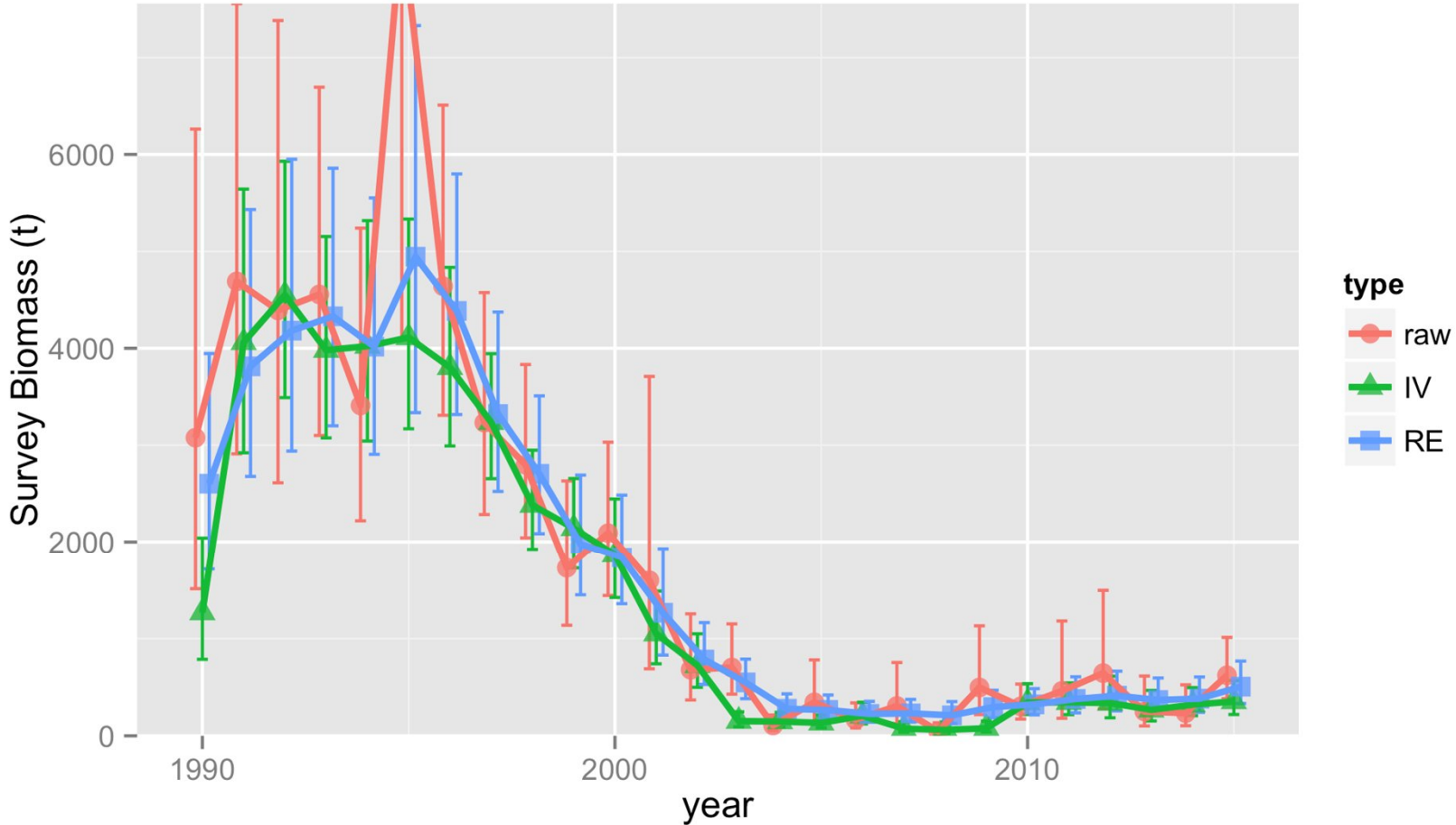
## Averaging results (1)



## Averaging results (2)



# Averaging results (3)



## Averaging results (3)

### New Survey Standardization

quantity	units	Raw	IV	RE
Projected MMB	t	missing1	317.6040582	454.940123
$B_{MSY}$	t	missing2	5012.1154242	5012.1154242
stock status			overfished	overfished
$F_{OFL}$	$year^{-1}$	missing3	0	0
$RM_{OFL}$	t	missing4	0	0
$DM_{OFL}$	t	missing5	0.2560223	0.2986122
$OFL$	t	missing6	0.1280111	0.1493061

Type	current survey MMB (t)	$B_{MSYproxy}$ (t)
Raw	621.7	5012.1
IV	352.9	3274.9
RE	505.5	4109.1

### Old Survey Standardization

quantity	units	Raw	IV	RE
Projected MMB	t	missing1	317.2714406	455.3479237
$B_{MSY}$	t	missing2	4002.4982102	4002.4982102
stock status			overfished	overfished
$F_{OFL}$	$year^{-1}$	missing3	0	0
$RM_{OFL}$	t	missing4	0	0
$DM_{OFL}$	t	missing5	0.2558485	0.2987104
$OFL$	t	missing6	0.1279243	0.1493552



## Status determination and OFL calculation

- The time series of MMB-at-mating to determine  $B_{MSY}$  for this stock was estimated using “raw” survey MMB to start the calculation
- The MMB-at-mating for 2015/16 was calculated by projecting an IV average of MMB-at-survey for this year and last year forward to mating, using a 3-year average estimator for the ratio of bycatch mortality to MMB-at-fishery to estimate the projected bycatch mortality for 2015/16.
- Stock in Tier 4c:  $B/B_{msy} \sim 6\%$
- SSC recommended Tier 5 approach to OFL based on average bycatch over 1999/2000-2005/06.



# Basis for the OFL

Stock is overfished.

All weights in t.

Year	Tier	$B_{MSY}$	Current $MMB_{mating}$	$B/B_{MSY}$ ( $MMB_{mating}$ )	$\gamma$	Years to define $B_{MSY}$	Natural Mortality	P*
2011/12	4c	4,209	365	0.09	1	1975/76-1984/85 & 1990/91-1997/98	0.18	10% buffer
2012/13	4c	4,494	496	0.11	1	1980/81-1984/85 & 1990/91-1997/98	0.18	10% buffer
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	5,012	318	0.06	1	1980/81-1984/85 & 1990/91-1997/98	0.18	25% buffer

All weights in million lbs.

Year	Tier	$B_{MSY}$	Current $MMB_{mating}$	$B/B_{MSY}$ ( $MMB_{mating}$ )	$\gamma$	Years to define $B_{MSY}$	Natural Mortality	P*
2011/12	4c	9.28	0.80	0.09	1	1975/76-1984/85 & 1990/91-1997/98	0.18	10% buffer
2012/13	4c	9.91	1.09	0.11	1	1980/81-1984/85 & 1990/91-1997/98	0.18	10% buffer
2013/14	4c	8.79	0.61	0.07	1	1980/81-1984/85 & 1990/91-1997/98	0.18	10% buffer
2014/15	4c	8.82	0.48	0.05	1	1980/81-1984/85 & 1990/91-1997/98	0.18	25% buffer
2015/16	4c	11.05	0.70	0.06	1	1980/81-1984/85 & 1990/91-1997/98	0.18	25% buffer

# Management Performance

Overfishing is not occurring.

All units are tons of crab and the OFL is a total catch OFL for each year:

Year	MSST	Biomass (MMB <sub>matng</sub> )	TAC	Retained Catch	Total Catch Mortality	OFL	ABC
2011/12	2,247 <sup>A</sup>	365 <sup>A</sup>	0	0	0.36	1.16	1.04
2012/13	1,994 <sup>A</sup>	579 <sup>A</sup>	0	0	0.61	1.16	1.04
2013/14	2,001 <sup>A</sup>	225 <sup>A</sup>	0	0	0.03	1.16	1.04
2014/15	2,506 <sup>A</sup>	320 <sup>A</sup>	0	0	0.07	1.16	0.87
2015/16	--	318 <sup>B</sup>	--	--	--	1.16	0.87

All units are million pounds of crab and the OFL is a total catch OFL for each year:

Year	MSST	Biomass (MMB <sub>matng</sub> )	TAC	Retained Catch	Total Catch Mortality	OFL	ABC
2011/12	4.95 <sup>A</sup>	0.80 <sup>A</sup>	0	0	0.0008	0.003	0.002
2012/13	4.39 <sup>A</sup>	1.09 <sup>A</sup>	0	0	0.0013	0.003	0.002
2013/14	4.41 <sup>A</sup>	0.50 <sup>A</sup>	0	0	0.0001	0.003	0.002
2014/15	5.52 <sup>A</sup>	0.71 <sup>A</sup>	0	0	0.0002	0.003	0.002
2015/16	--	0.70 <sup>B</sup>	--	--	--	0.003	0.002

- OFL based on average catch (1999/2000-2005/06)
- ABC based on 25% buffer (CPT rec'd, SSC approved 2014)