Tanner Crab Harvest Strategy Analysis

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Today's presentation

Part A

- Background
- Department analysis and recommendations
  - Female maturity definition
  - Area used for female threshold
  - Years for female threshold
  - ½ TAC penalty

Part B

- Alternatives to female open/close threshold
  - Further consideration: sliding control rule, model data
  - Risk analyses for component alternatives

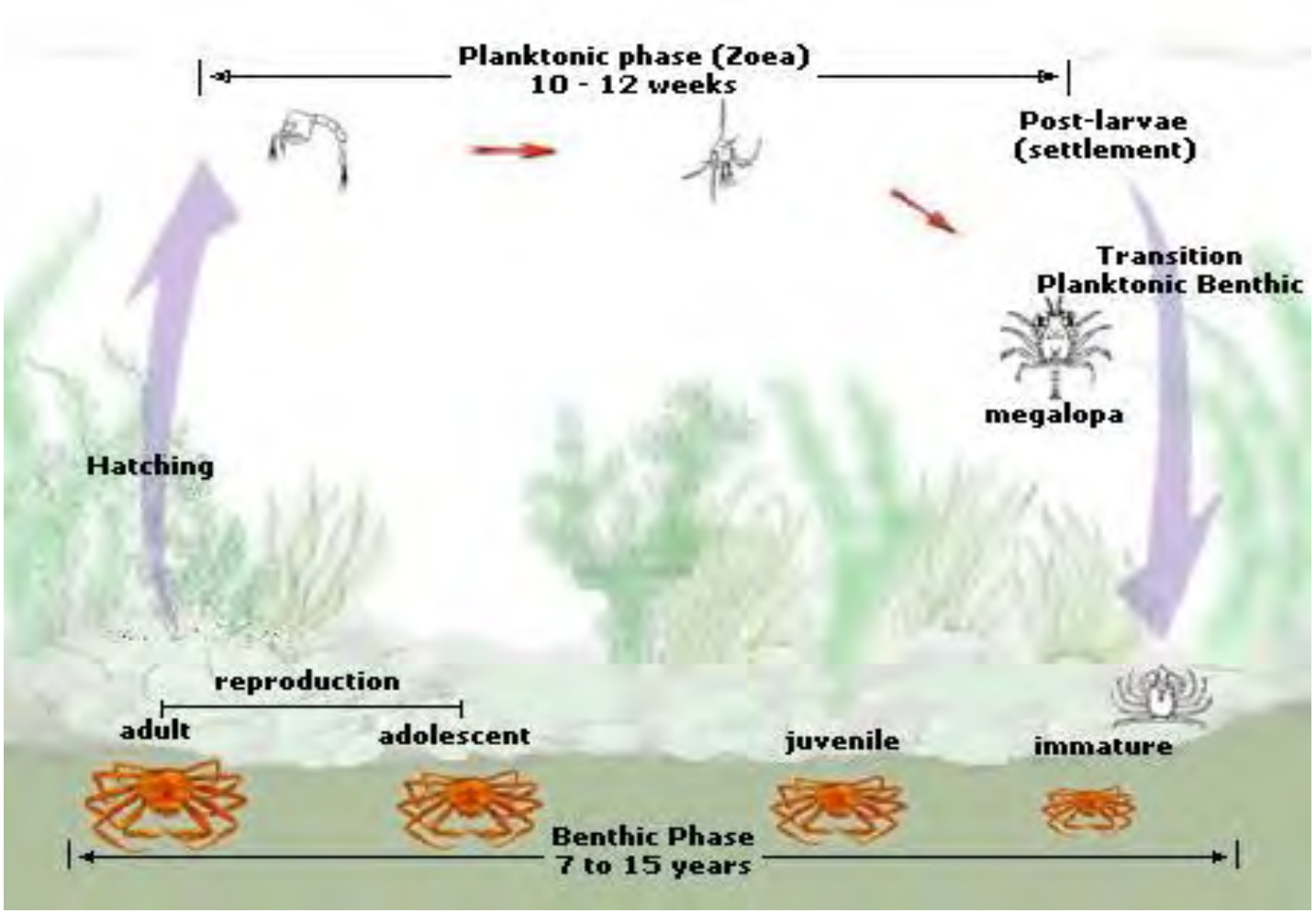
Board Generated Proposal

A. Criteria used to determine mature female Tanner crab (size-cut vs actual);
B. Area used to estimate female biomass (i.e., west of 173° W. long);
C. Years used to estimate long-term average mature female biomass;
D. Utility of ½ TAC penalty: Provision that TAC is reduced 50% in any year succeeding a year in which the mature female Tanner crab biomass falls below threshold.

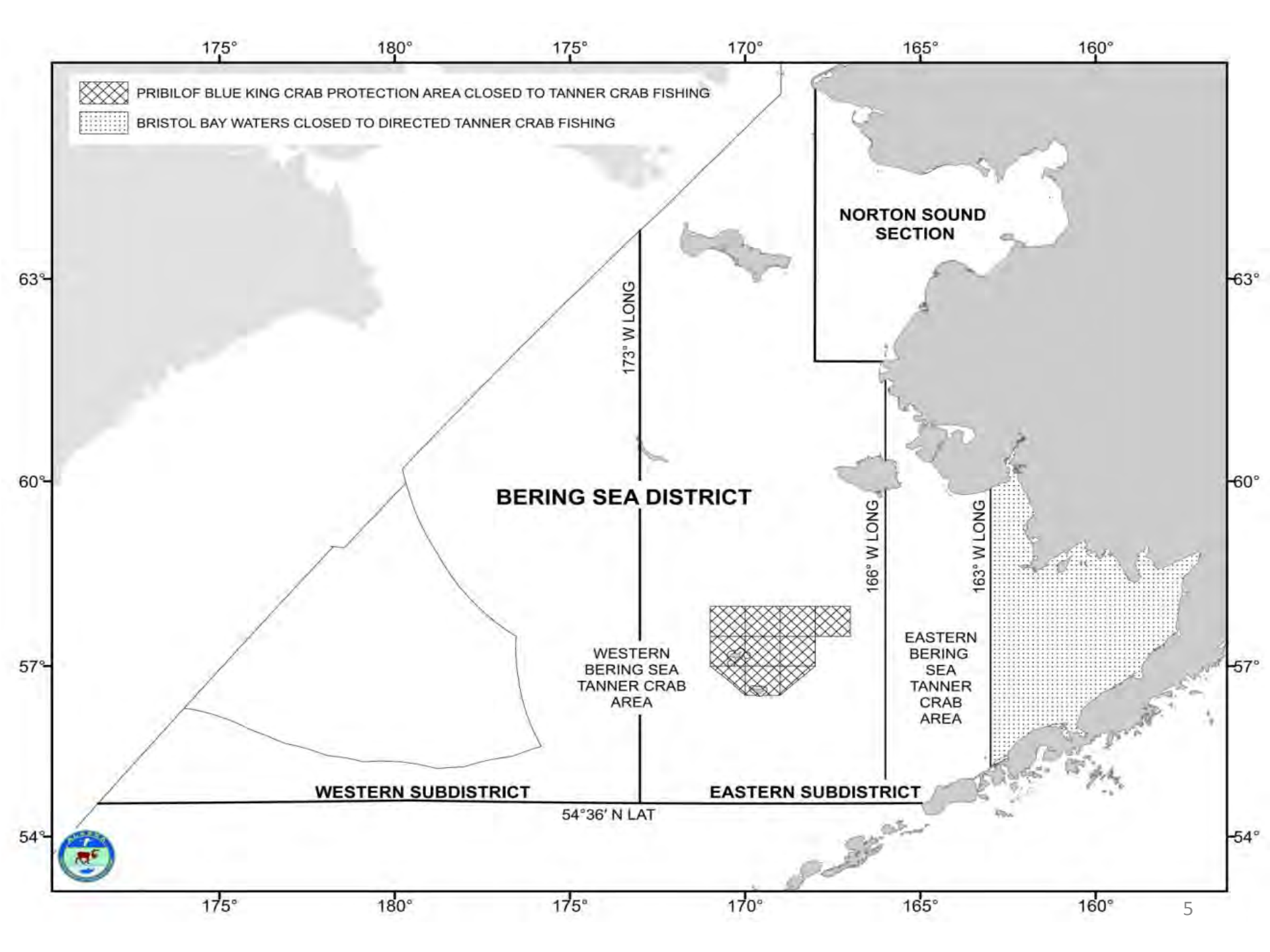
<u>Other Elements of Interest</u>

E. Alternatives to a single open/close threshold (i.e., alternatives to the on/off switch to facilitate flexibility)
F. Consider upper male threshold to determine harvestable surplus

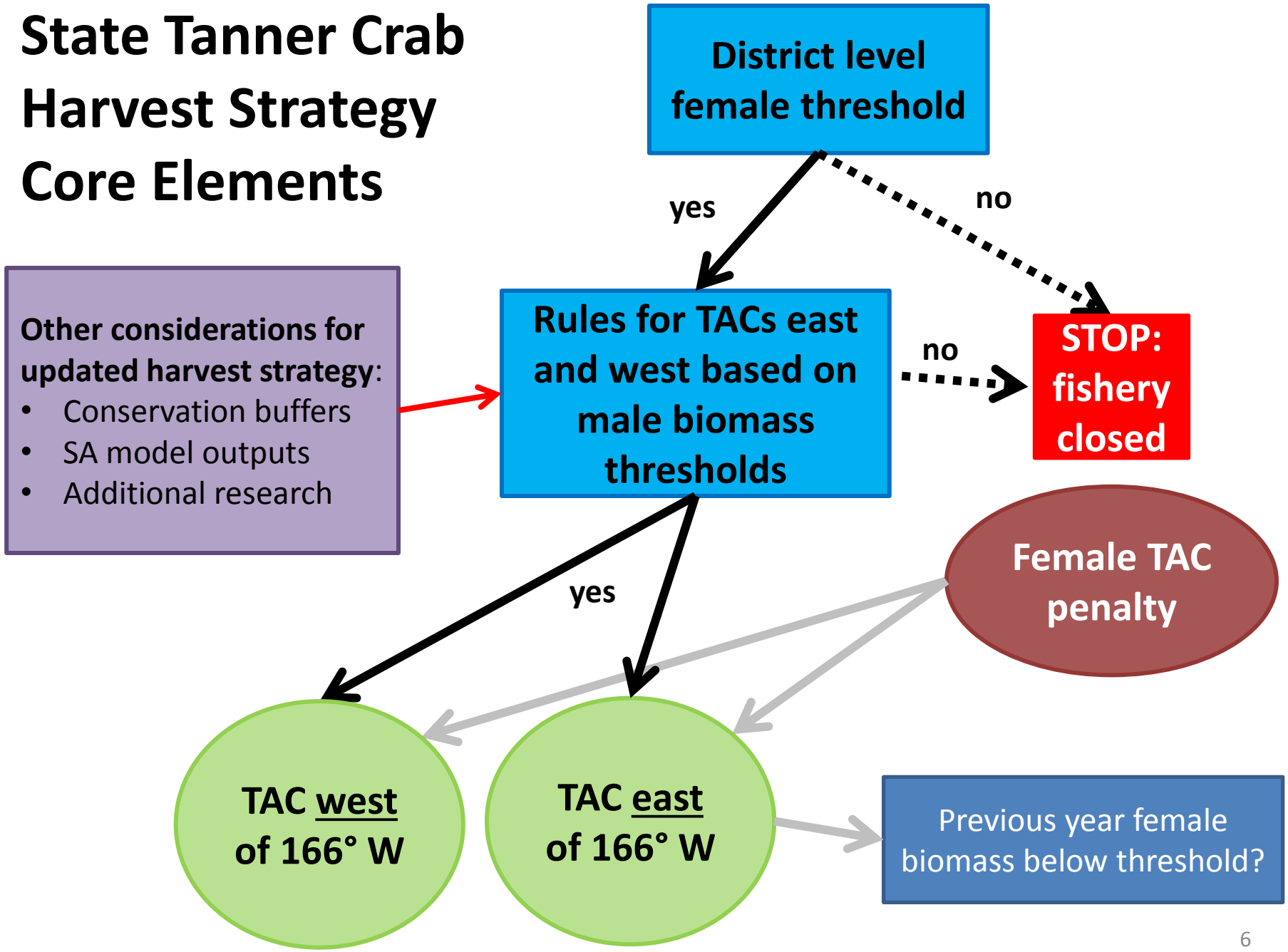
Life History Overview



Source: http://www.glf.dfo-mpo.gc.ca/sci-sci/crab-crab/bio-bio-e.html


175°
180°
175°
170°
165°
160°
PRIBILOF BLUE KING CRAB PROTECTION AREA CLOSED TO TANNER CRAB FISHING
BRISTOL BAY WATERS CLOSED TO DIRECTED TANNER CRAB FISHING
NORTON SOUND SECTION
63°
173° W LONG
BERING SEA DISTRICT
60°
166° W LONG
163° W LONG
57°
WESTERN BERING SEA TANNER CRAB AREA
EASTERN BERING SEA TANNER CRAB AREA
WESTERN SUBDISTRICT
EASTERN SUBDISTRICT
54°36′ N LAT
54°

State Tanner Crab Harvest Strategy Core Elements



Harvest strategy updated in 2011

- **Female threshold:** 40% of 1975-2010 average of mature female biomass in Eastern Subdistrict
- **Male harvest rates**:
  - 0 when biomass is less than 25% of 1975-2010 average
  - **$(0.9)x(B/B_{AVE})xC_{MSY}$** when biomass is between 25-100% of 1975-2010 average
  - **$(0.9)xC_{MSY}$** when biomass is ≥ 1975-2010 average
- **Legal harvest cap**: 50% of exploitable legal males
- **Separate east-west management at 166°W**
- **½ reduction rule**: reduce TACs to ½ of computed value if previous years failed to meet thresholds

Evolution of female threshold calculation

1999

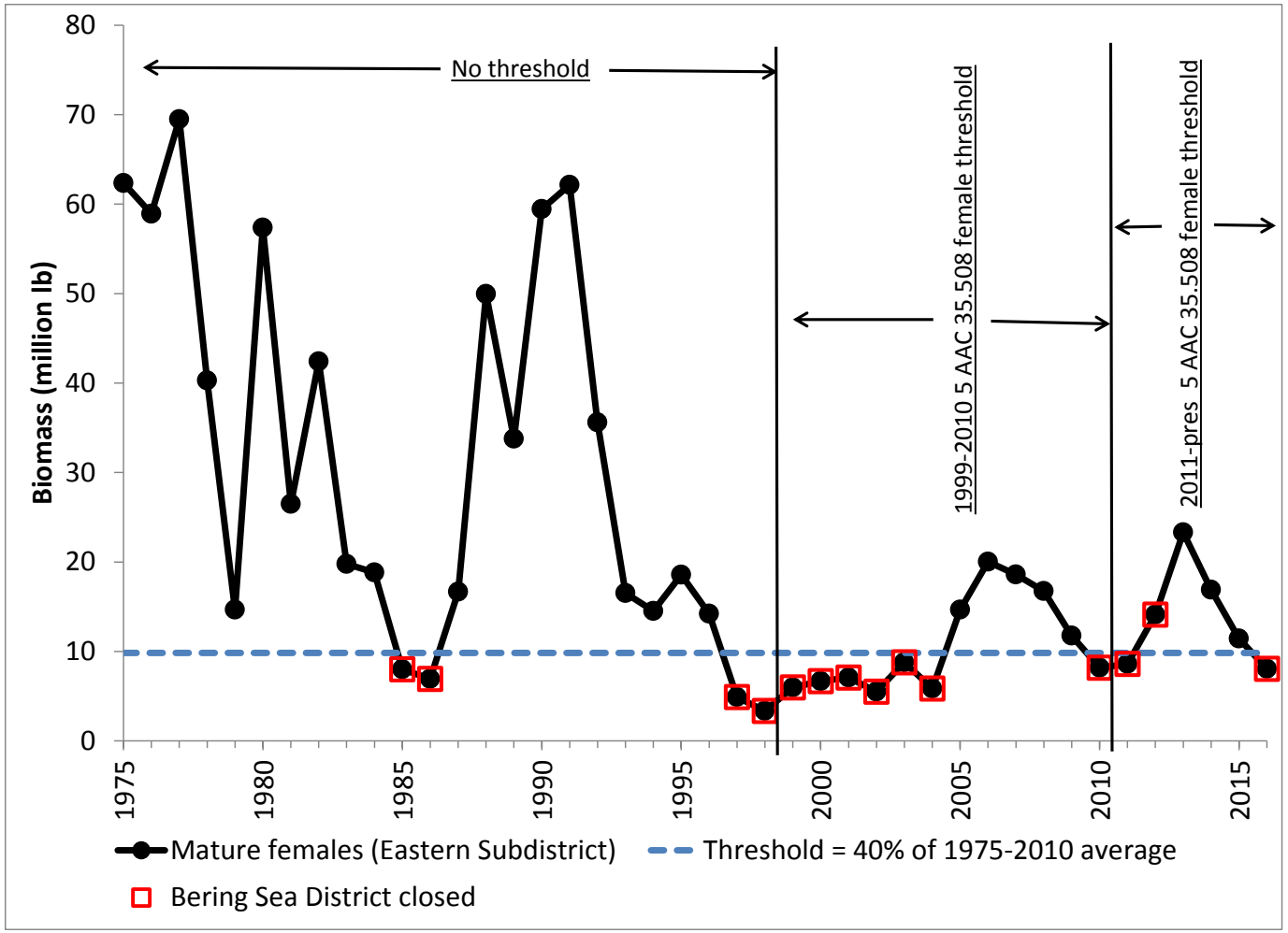
- The Board's policy on K&T specifies the use of a threshold below which the fishery must be closed to maintain adequate brood stock. Because the S-R relationship is weakly density dependent, we did not attempt to estimate an optimal threshold. Rather we set a threshold based on past fishery management practice and partly on the S-R relationship. In the past, the effective spawning biomass was always below 15.5 million lbs. when fishery was closed. This level of effective spawning biomass is slightly above the smallest effective spawning biomass with an above average recruitment level (Zheng and Kruse 1999).

- Threshold (15.5 million lbs) ……for Bristol Bay crab can be expanded to the EBS by dividing by 0.75 (Zheng and Kruse 1999). **21 million lbs**

2011

- The mature female biomass threshold in the proposed harvest strategy is set at 40% of the long-term average of the annual mature female biomass during 1975-2010, *which approximates the 21 million lb mature female biomass threshold in the current harvest strategy* (Zheng and Pengilly 2011).

Current Regs: Female Threshold



Threshold as currently defined in 5 AAC 35.508 (a) is a precautionary estimate of the "minimum stock size that allows for sufficient recruitment so that the stock can rebuild itself."

Why Females?

- Low female abundance = low egg production → low capacity to produce future recruitment
- Predictor of male population abundance
- Fishery closures meant to preserve females AND males
  - Females: egg production
  - Males: available for future recruitment of females
- Causes for declines in females is unknown
  - Likely environmental: unfavorable conditions
  - Closures are conservation measure in periods of low production and when causes are poorly understood
- BOF policy #5: *"Maintain adequate broodstock……fisheries must remain closed until there is adequate broodstock."*

Why Females?

What is the "*minimum stock size that allows for sufficient recruitment so that the stock can rebuild itself*"?

- **Unknown.** Threshold set at precautionary level.

How to estimate "broodstock"?

- **ESB (effective spawning biomass)**: difficult for Tanner because of poorly fitting spawner/recruit relationship.
  - Mechanisms for recruitment poorly understood
  - Need more info on Tanner mating dynamics
- **Fertilized egg production** (egg production index)
  - Some data limitations
  - Relies on assumptions about stability of size/fecundity relationship: does it vary over time?
- **Mature female biomass** currently best proxy

Why Females?

"Over the long term, Tanner crab productivity [in the eastern Bering Sea] should be evaluated based on better measures of spawning biomass than mature male biomass, as is currently used, which ignores the dominant role of females in reproduction" (Report of the Scientific and Statistical Committee to the North Pacific Fishery Management Council, Minutes October 1–3, 2012. North Pacific Fishery Management Council, Anchorage).

Maturity Definition

Board Generated Proposal

A. **Criteria used to determine mature female Tanner crab (size-cut vs actual);**
B. Area used to estimate female biomass (i.e., west of 173° W. long);
C. Years used to estimate long-term average mature female biomass;
D. Utility of ½ TAC penalty: Provision that TAC is reduced 50% in any year succeeding a year in which the mature female Tanner crab biomass falls below threshold.

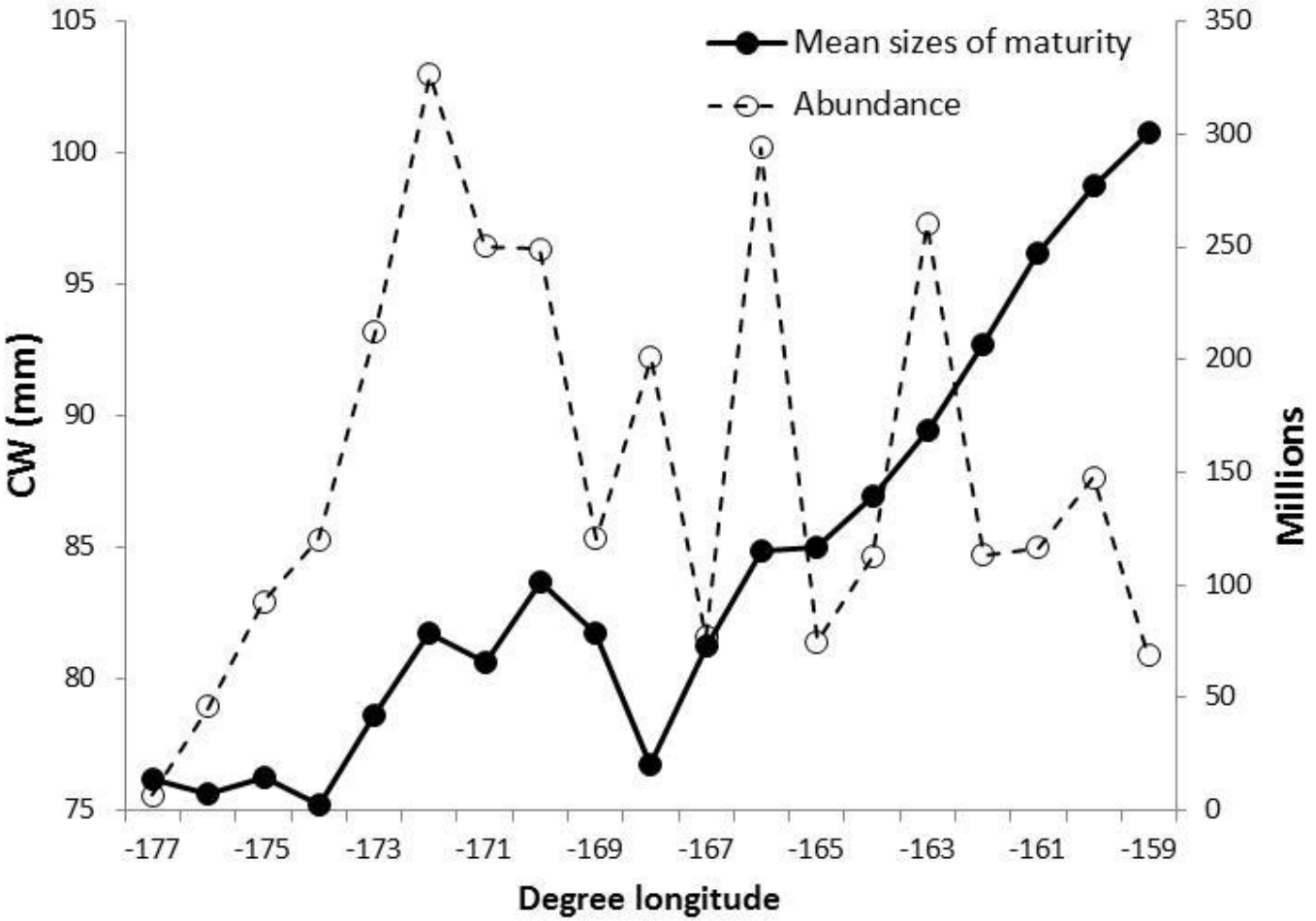
<u>Other Elements of Interest</u>

E. Alternatives to a single open/close threshold (i.e., alternatives to the on/off switch to facilitate flexibility)
F. Consider upper male threshold to determine harvestable surplus

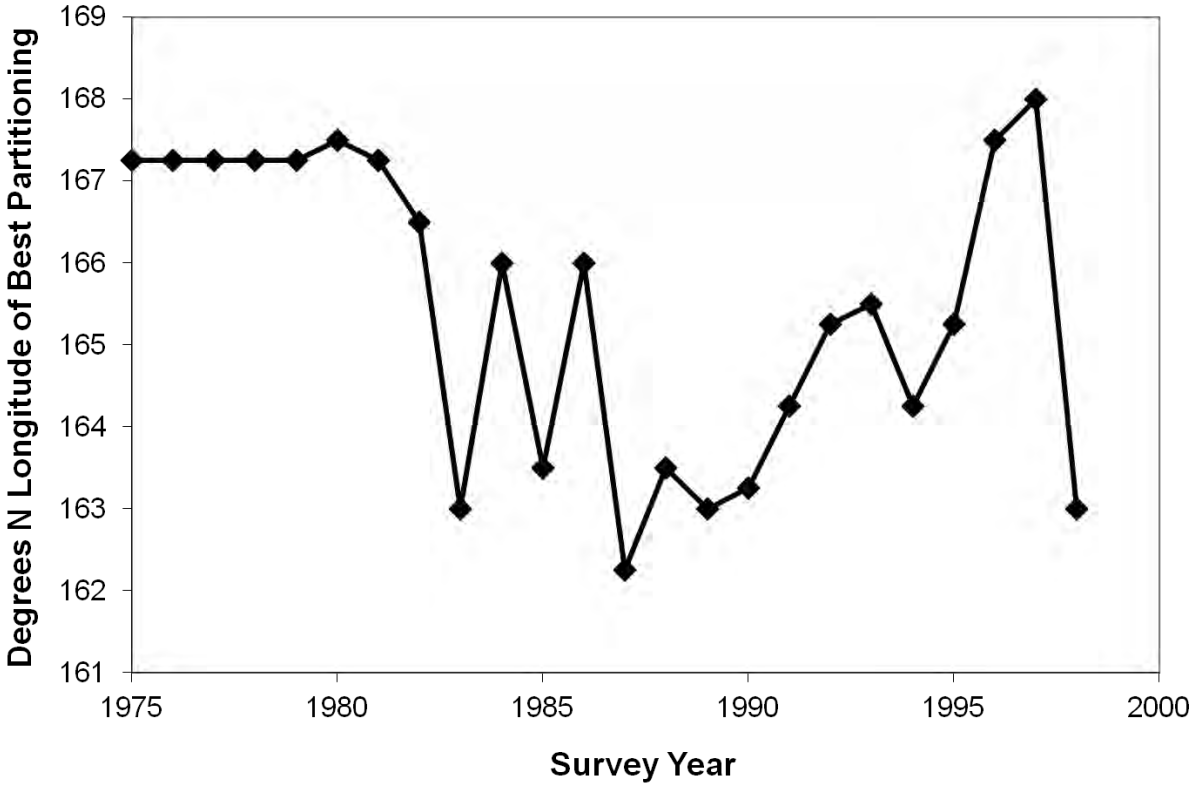
Current Regs Define Maturity by Size

1. **Stock threshold for opening fishery:**
   - Mature female biomass @ survey in Eastern Subdistrict ≥ 40% of 1975-2010 avg
     - "Eastern Subdistrict" = Bering Sea District east of 173° W long
     - 40% of 1975-2010 avg = (0.40)x(24.581-mill lb) = **9.832-mill lb**
       - Based on revised NMFS area-swept estimates (value is not in 5 AAC 35.508)
     - "mature female" = ♀♀≥ 85 mm CW in area east of 166° W long.
     - "mature female" = ♀♀≥ 80 mm CW in area 166° - 173° W long.

Female maturity



Complications: Temporal-Spatial Trends



Longitude of "best partitioning" of EBS Tanners by ♀ size at maturity not stable:

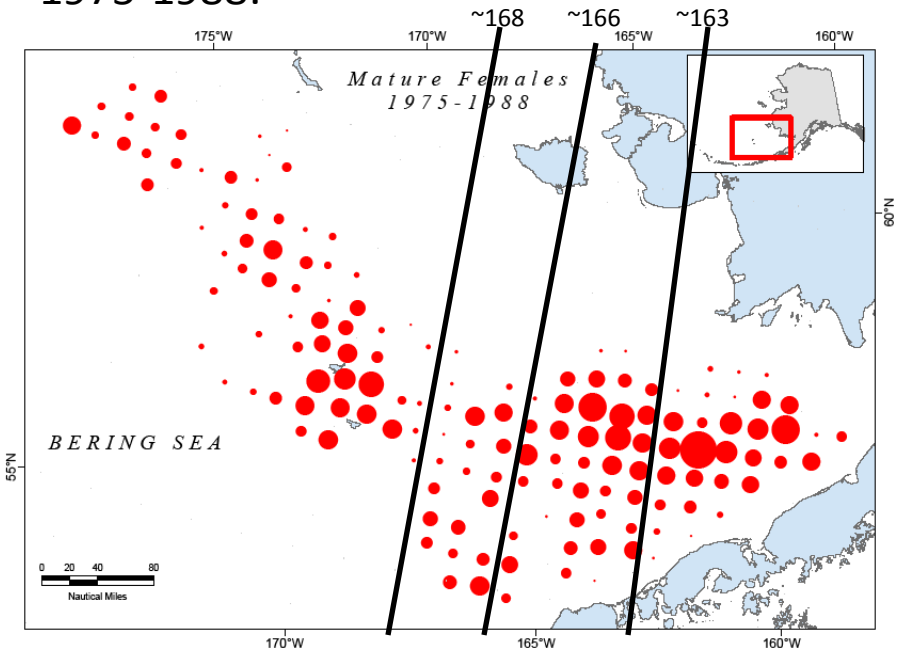
Application of Somerton's method for determining longitude for "best partitioning" of eastern Bering Sea Tanner crab distribution by NMFS EBS trawl survey station mean size of adult females, 1975−1998: Longitude of "best partitioning" of eastern Bering Sea Tanner crab distribution by size of mature females at 167°15' W longitude does not hold after 1979.

Otto and Pengilly (2002)

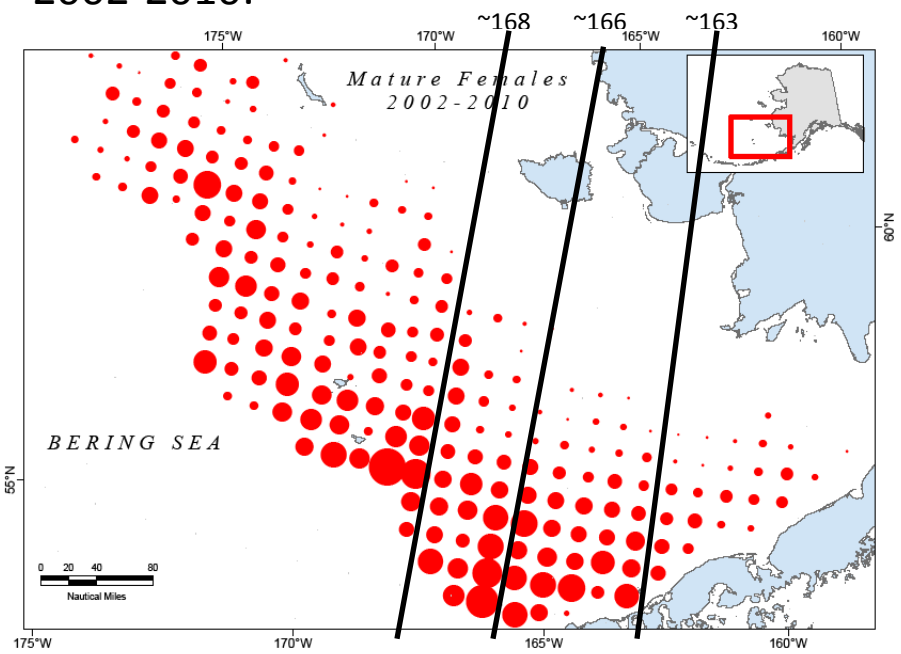
Complications: Temporal-Spatial Trends

Change in distribution of mature females (NMFS EBS trawl survey)

1975-1988:



2002-2010:



Zheng (2008), Zheng and Pengilly (2011)

Spatio-temporal Complications in Female Maturity

- Generally, mature females get smaller moving west
- Actual mean size maturity changes over time
- Spatial distribution shifts over time
- Line of best partitioning based on female mean size at maturity changes over time

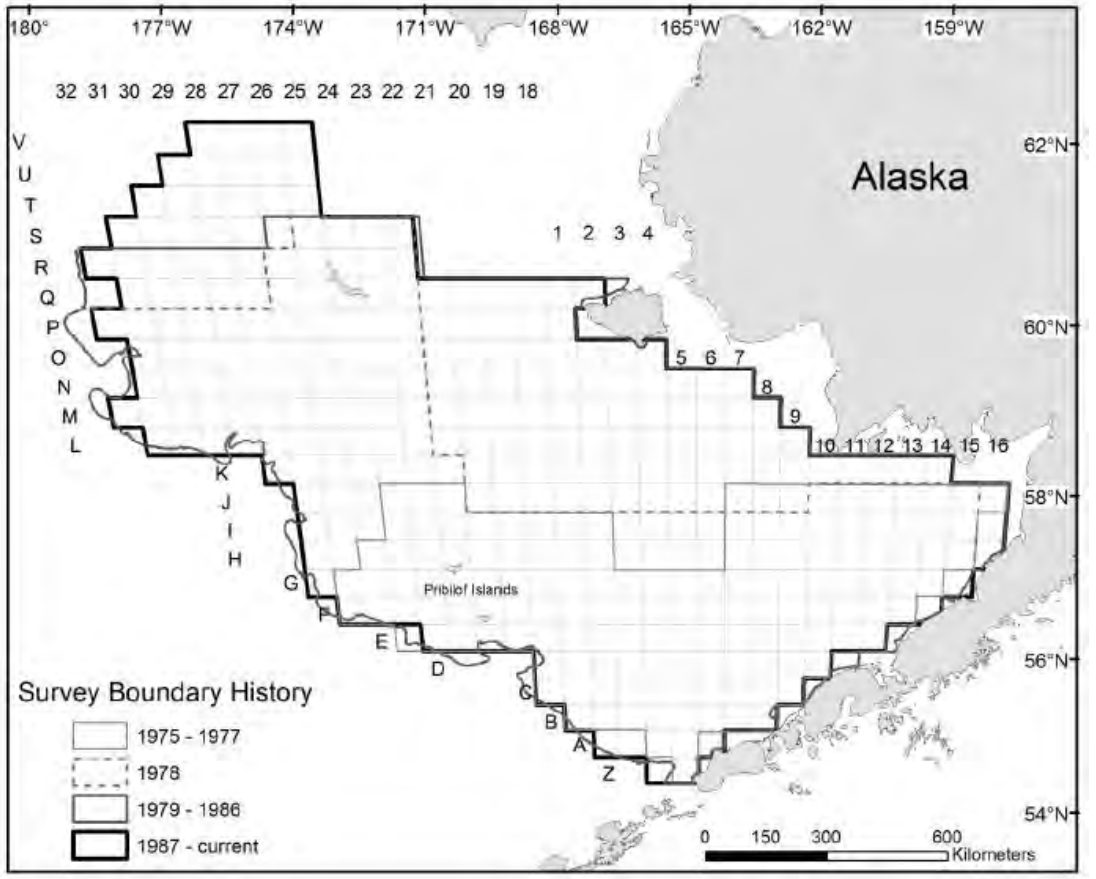
NOAA EBS bottom trawl survey

Time span: 1975-present

Spatial coverage:

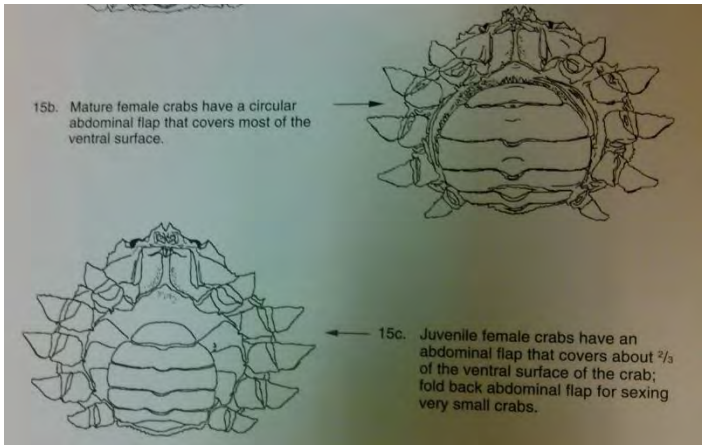
Biological data:

- Size
- Sex
- Maturity
- Shell condition
  - Proxy for age
- Egg condition

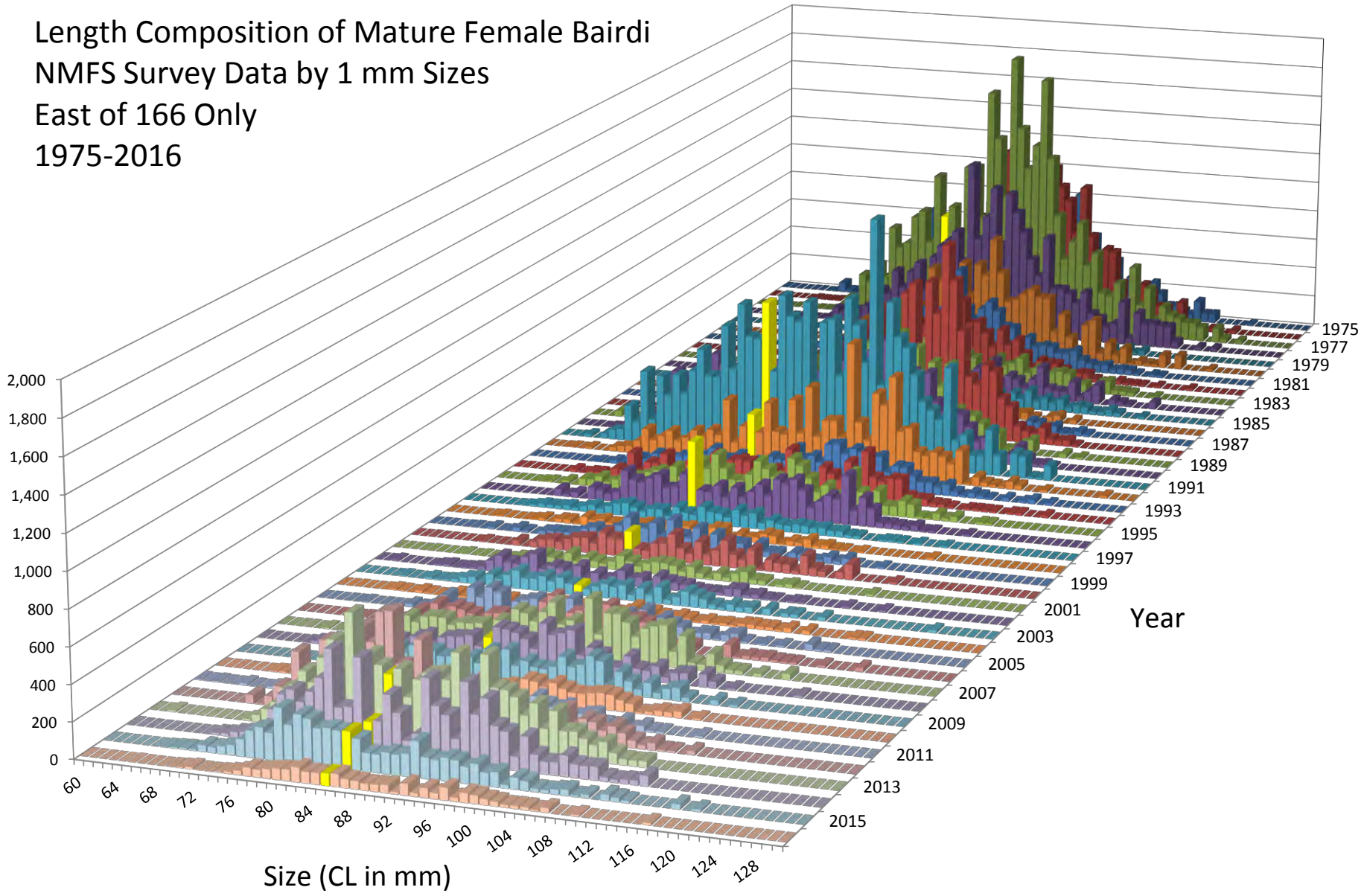


NOAA EBS bottom trawl survey

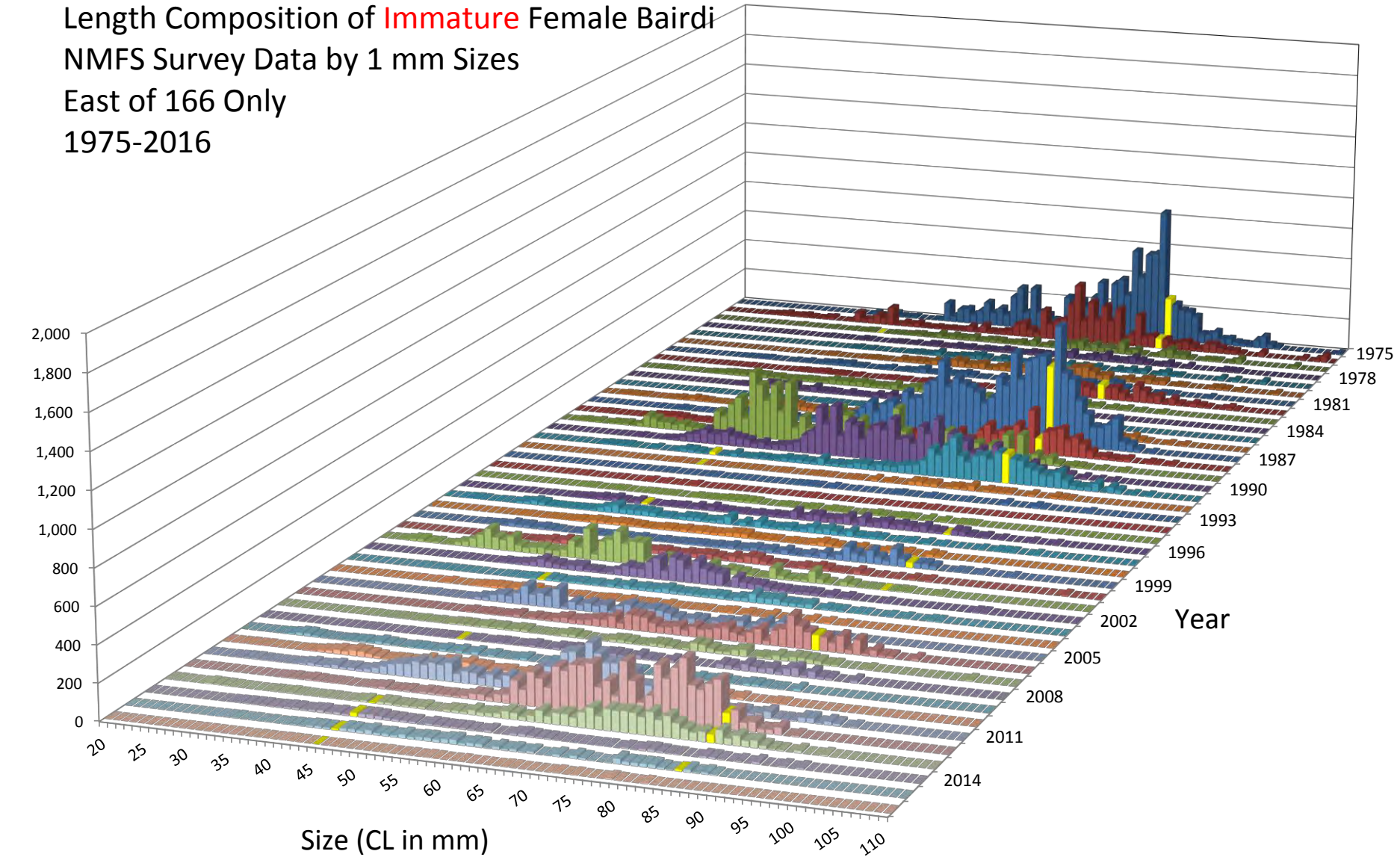
Each female measured is scored for size and maturity (by egg presence and/or shape of abdominal flap).

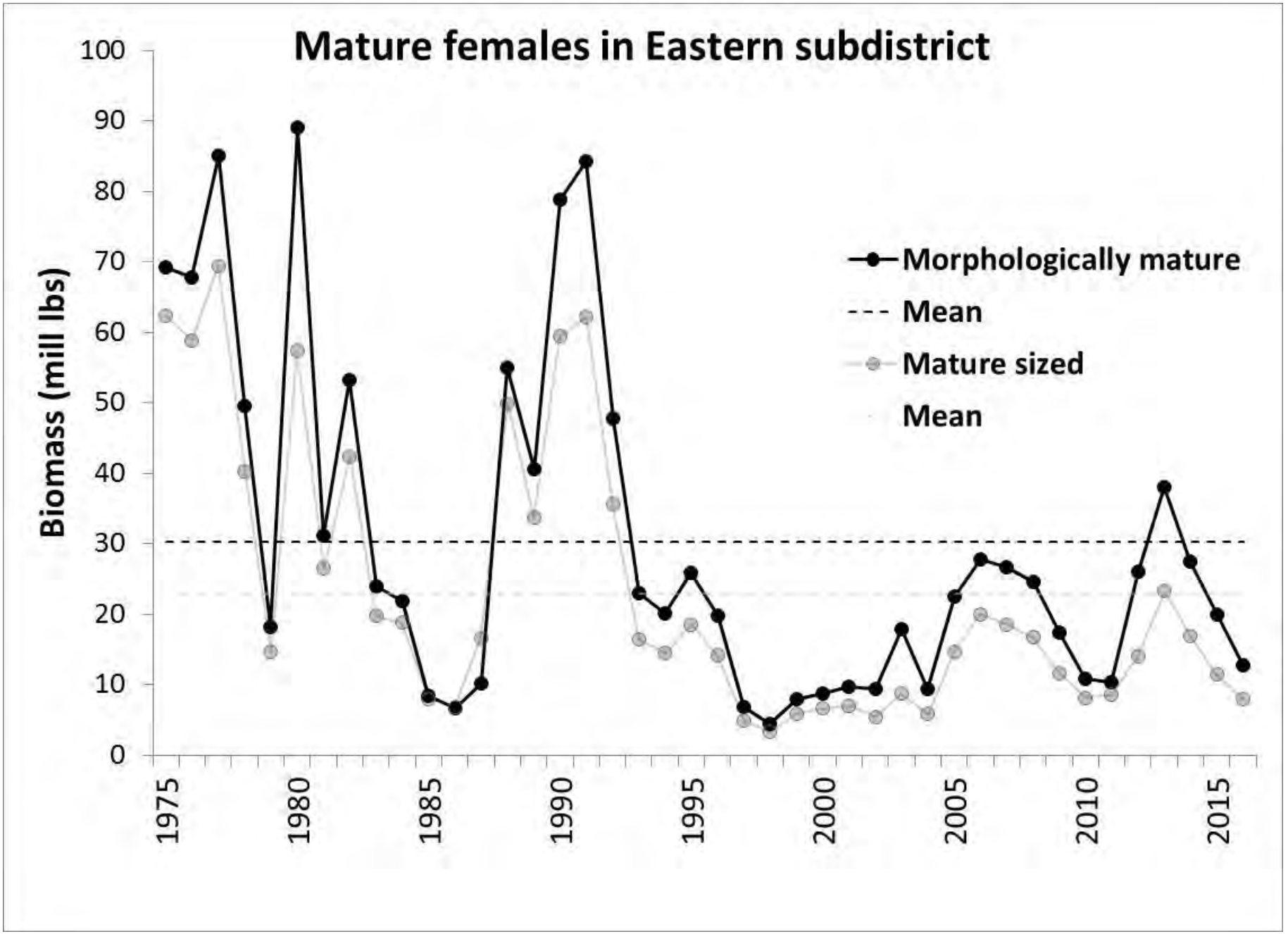


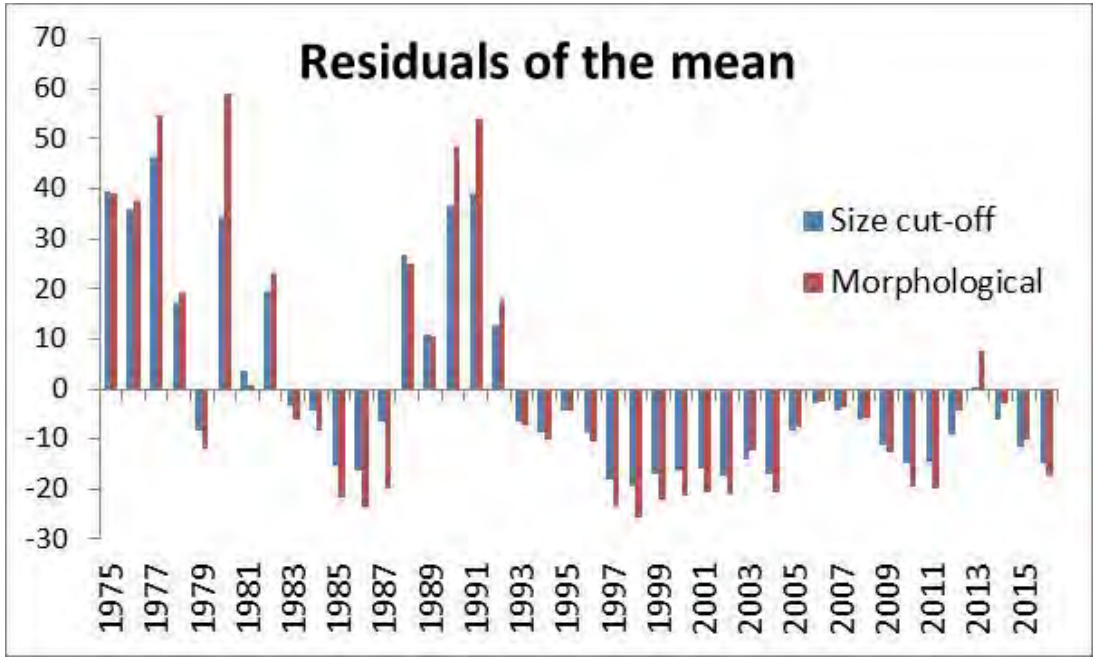
Length Composition of Mature Female Bairdi
NMFS Survey Data by 1 mm Sizes
East of 166 Only
1975-2016

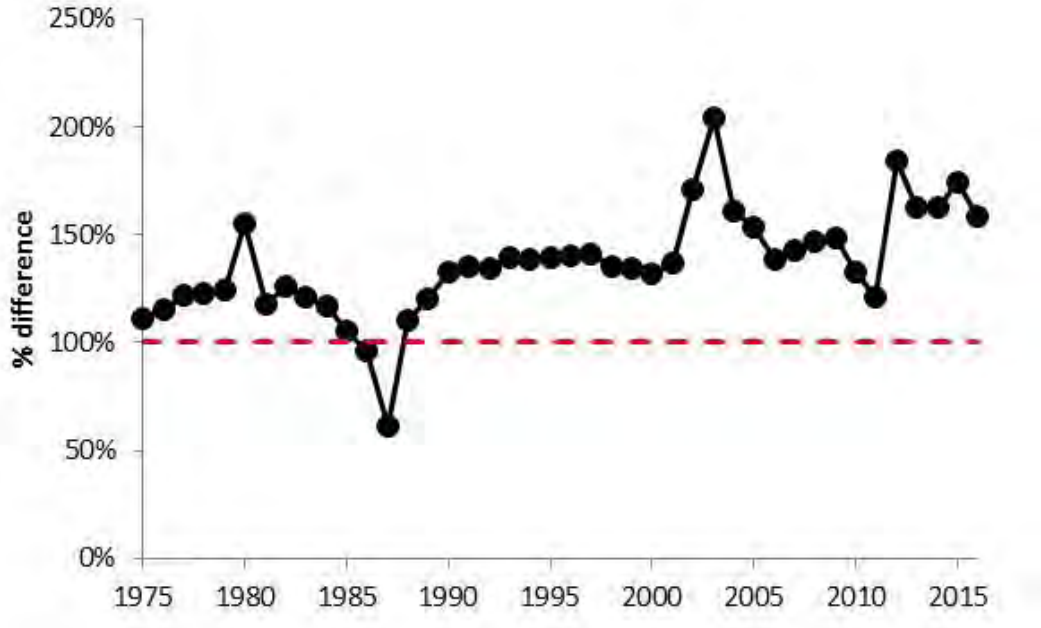


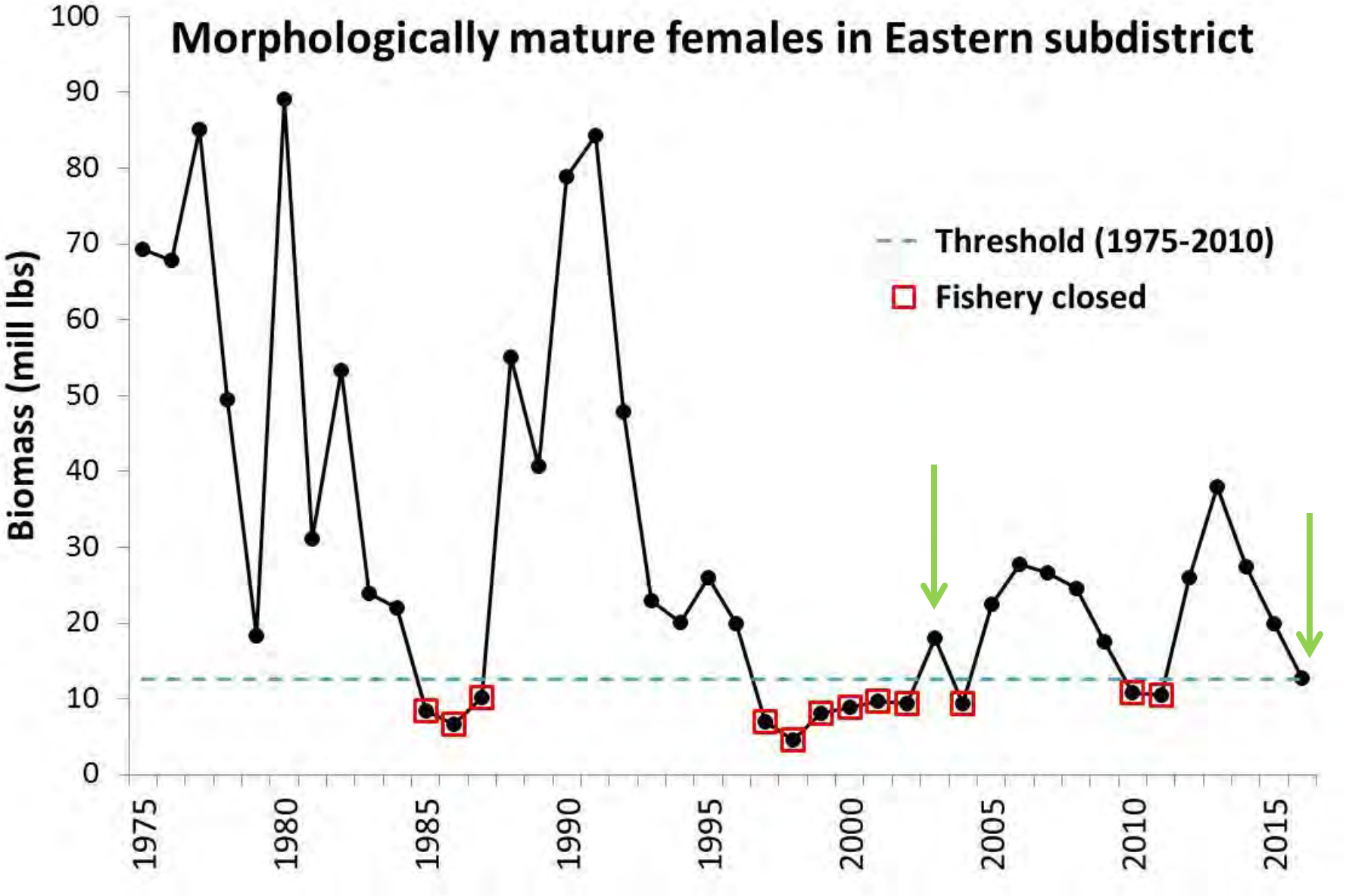
Length Composition of Immature Female Bairdi
NMFS Survey Data by 1 mm Sizes
East of 166 Only
1975-2016




Mature females in Eastern subdistrict
Biomass (mill lbs)
100
90
80
70
60
50
40
30
20
10
0
1975
1980
1985
1990
1995
2000
2005
2010
2015
Morphologically mature
Mean
Mature sized
Mean


Residuals of the mean
70
60
50
40
30
20
10
0
-10
-20
-30
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
Size cut-off
Morphological


% difference
250%
200%
150%
100%
50%
0%
1975
1980
1985
1990
1995
2000
2005
2010
2015


Morphologically mature females in Eastern subdistrict
Biomass (mill lbs)
100
90
80
70
60
50
40
30
20
10
0
1975
1980
1985
1990
1995
2000
2005
2010
2015
Threshold (1975-2010)
Fishery closed

Benefits of using morphological definition

- Data are available from NOAA survey
- Reconciles spatio-temporal changes in average size at maturity
  - Can't determine perfect size definition for all locations at all times
  - More accurate
- Consistent with how NMFS reports abundance estimates for mature females

Recommendation:
Define female maturity by abdominal flap morphology (i.e., “actual” maturity)

Years for Mature Female Threshold Calculation

Board Generated Proposal

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Year scenarios for mature female threshold consideration

- 1975-2010 (status quo)
- 1982-2010
- 1982-present
- 1977-present (1982-present lagged by 5 yrs)
- 1982-2016

Factors considered when thinking about survey years

Regime shift: widespread oceanographic and biological changes

- Shifts in EBS production
- Define years representative of current conditions

Survey spatial coverage

- Consistent spatial coverage?

Survey gear

- Consistent over time?
- Impacts selectivity

Importance of temporal range

- Should maximize temporal range as much as possible to capture population variability (highs and lows in timeseries) because it gives us the best picture of the current years relative abundance.

1976/77 EBS Regime Shift

Well documented regime shift in 1976/77:

- Widespread changes in atmospheric, oceanographic, and biological indices
- Strong ALPI, PDO, warmer temperatures
- Overall shift in production: plankton and fish stocks high
- **Theory:** pre-regime conditions were favorable for crabs and yielded higher production relative to post-regime conditions

1976/77 EBS Regime Shift

Federal Stock Assessment Model

2016 Tanner crab SAFE: *"The determination of B_{MSY}=$B_{35\%}$ for Tanner crab depends on the selection of an appropriate time period over which to calculate average recruitment (R). After much discussion in 2012 and 2013, the SSC endorsed an averaging period of 1982+. Starting the average recruitment period in 1982 is consistent with a 5-6 year recruitment lag from 1976/77, when a well-known climate regime shift occurred in the EBS (Rodionov and Overland, 2005) that may have affected stock productivity."*

Federal Tanner Stock Assessment Model

The **stock assessment model** time frame relates to recruitment as:

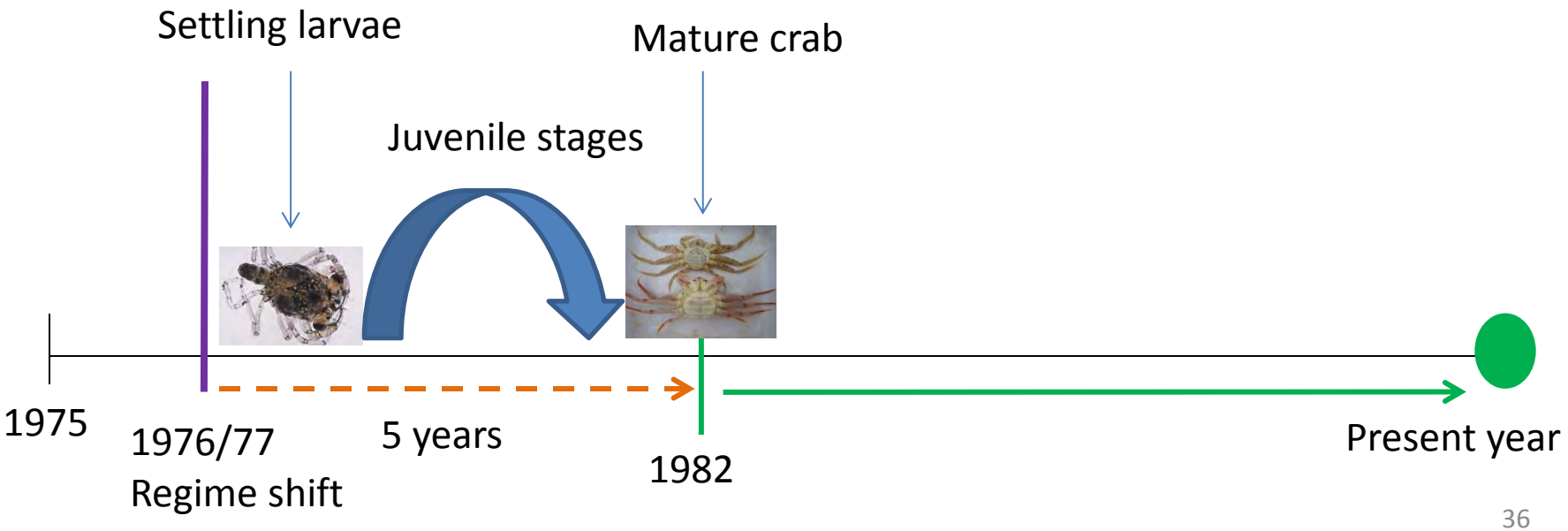
- "*The range of years …….refers to* ***the years at which recruits enter the modeled population, not the years at which fertilization is assumed to occur (the latter can be obtained by subtracting 5)***." ; p. 109 Appendix A to the 2013 SAFE report: Recruitment analysis for stock status determination and harvest recommendations

The **state** time frame relates to mature females (a representation of fertilization year)

  - a recruitment time period of 1982+ assumes a 5 year lag from fertilization (proxied by mature female biomass) in 1977

Assumptions about mature females and the regime shift

- Include only females that existed in the post 1976/77 regime shift era.
- Post-regime shift era starts with settling post-larvae in 1977.
- Assume females reach maturity 5 years after settlement (Donaldson and Adams 1989).
- **Start mature female calculation at 1982.**



NOAA survey gear

Pre-1982

- Trawls and accessories (bridles, doors, setbacks, etc.,) lacked standardization
  - Primarily rigging of footrope and setback

Identical net starting in 1982

- 83-112 Eastern otter trawl (83 ft headrope, 112 ft footrope)
- 60 cm setback in footrope
  - Increased abundances of flatfish:
    - better efficiency, better catchability, higher selectivity?

Survey Selectivity

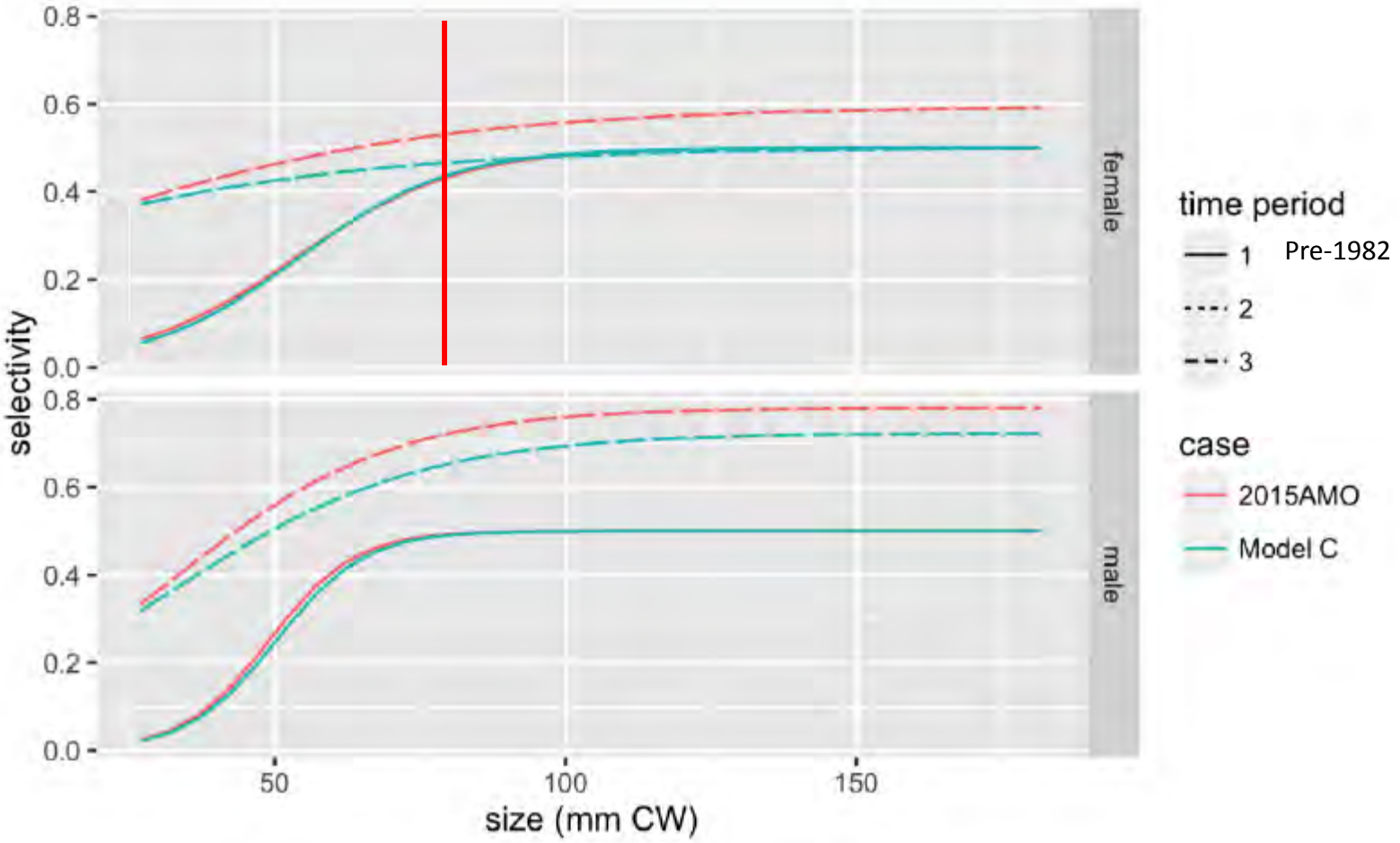
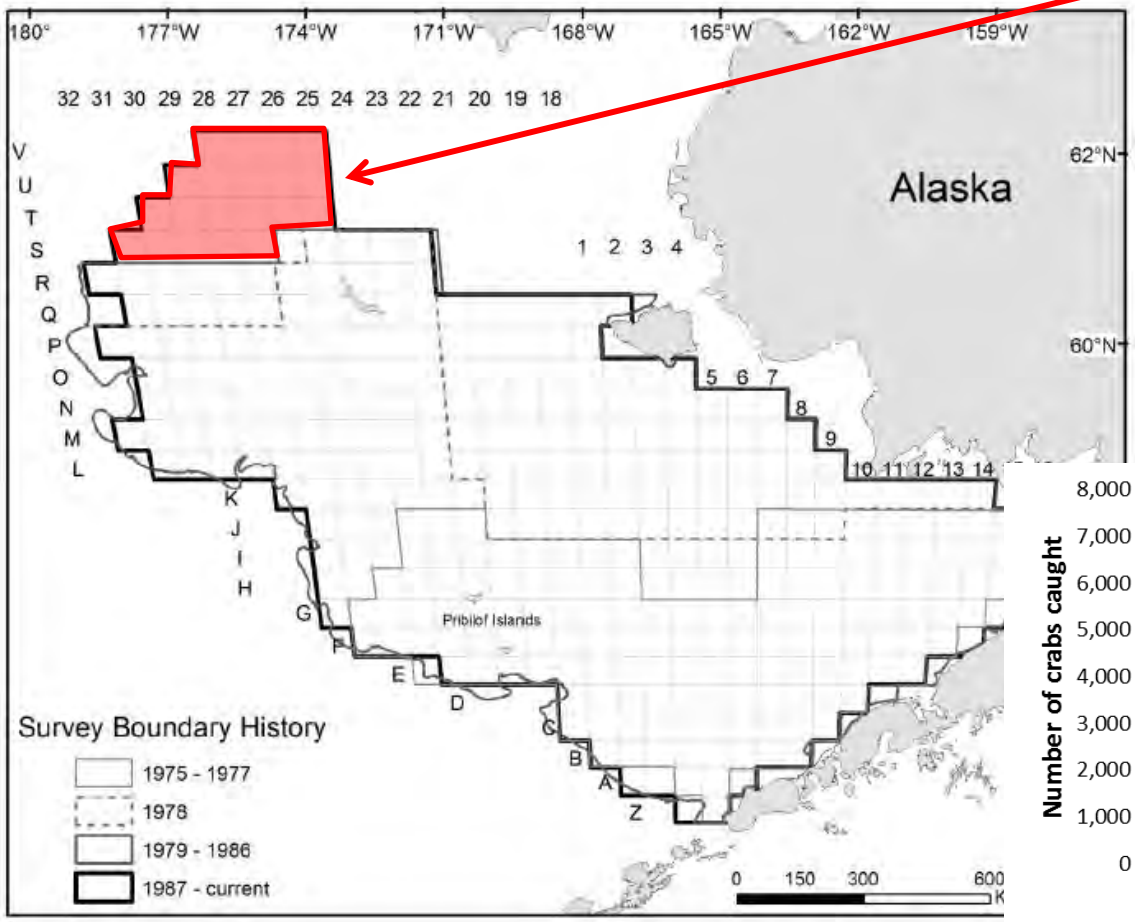


Figure 34. Estimated survey selectivity functions from the 2015 assessment (2015AMO) and the author's preferred model (Model C). Time periods: 1) pre-1982, 2) 1982-1986, 3) 1987-present.

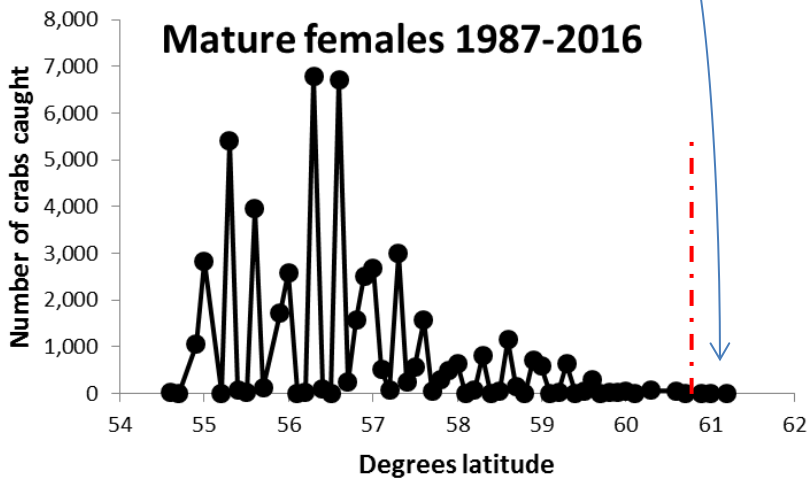
Survey Spatial Coverage



This area not surveyed prior to 1987.

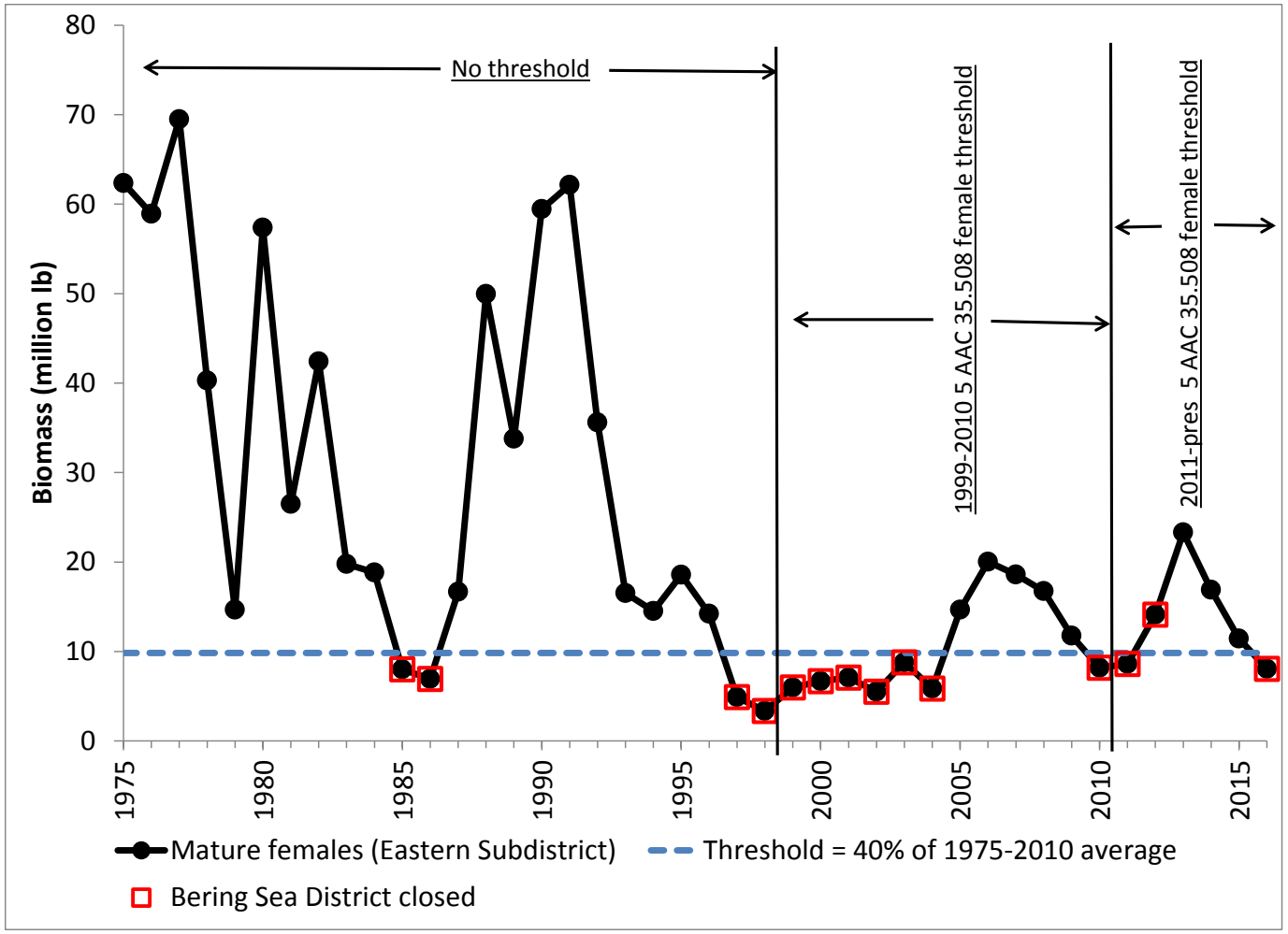
Appropriate to start calculation at 1982 of this area not surveyed from 1982-1986?

Virtually no mature females in this area during survey from 1987-2016

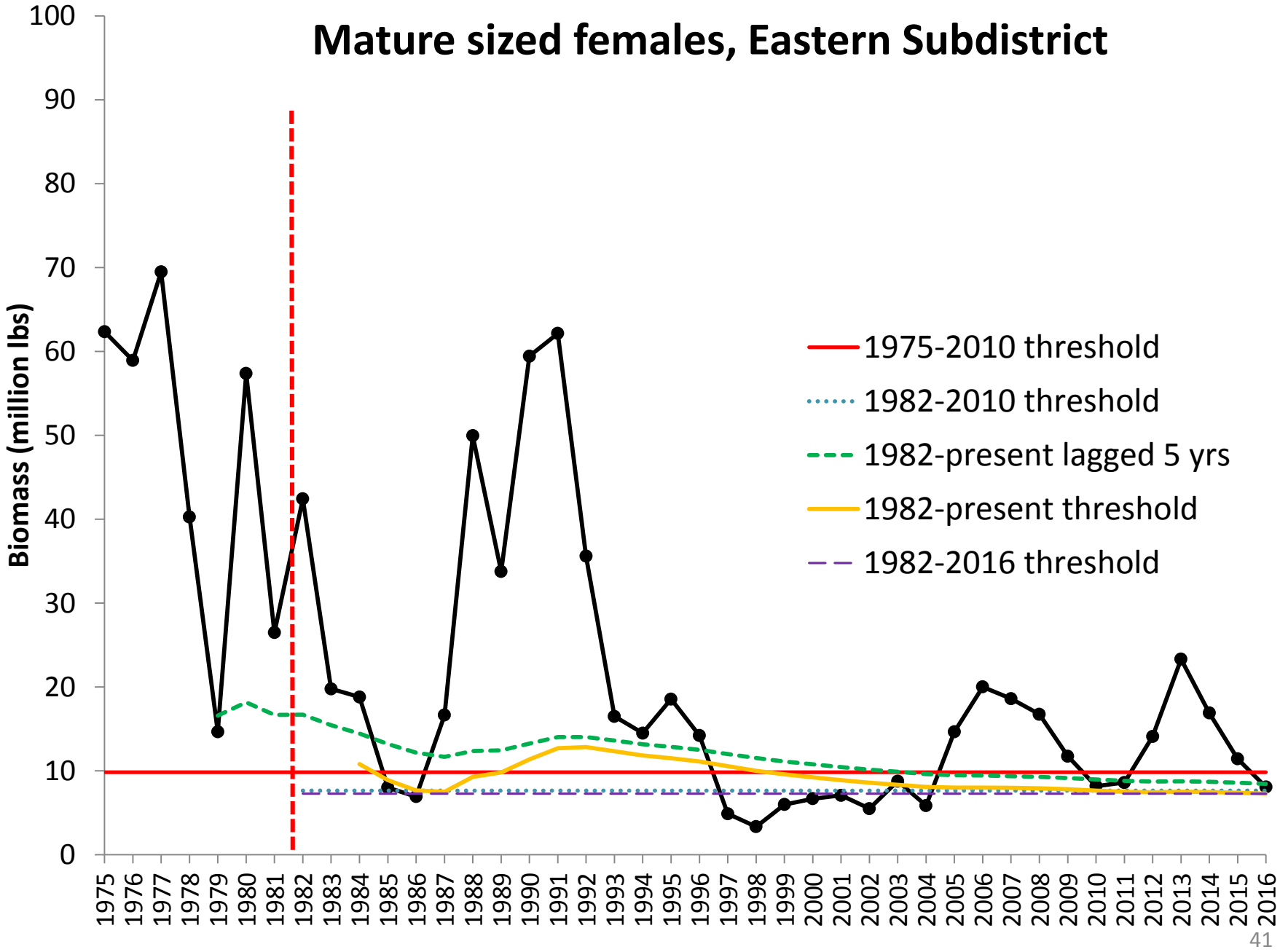


Safe to assume current survey spatial coverage is representative of female population back to 1982, including area not surveyed between 1982-1986.

Current Regs: Female Threshold



Threshold as currently defined in 5 AAC 35.508 (a) is a precautionary estimate of the "minimum stock size that allows for sufficient recruitment so that the stock can rebuild itself."


Mature sized females, Eastern Subdistrict
Biomass (million lbs)
100
90
80
70
60
50
40
30
20
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0
1975
1976
1977
1978
1979
1980
1981
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1983
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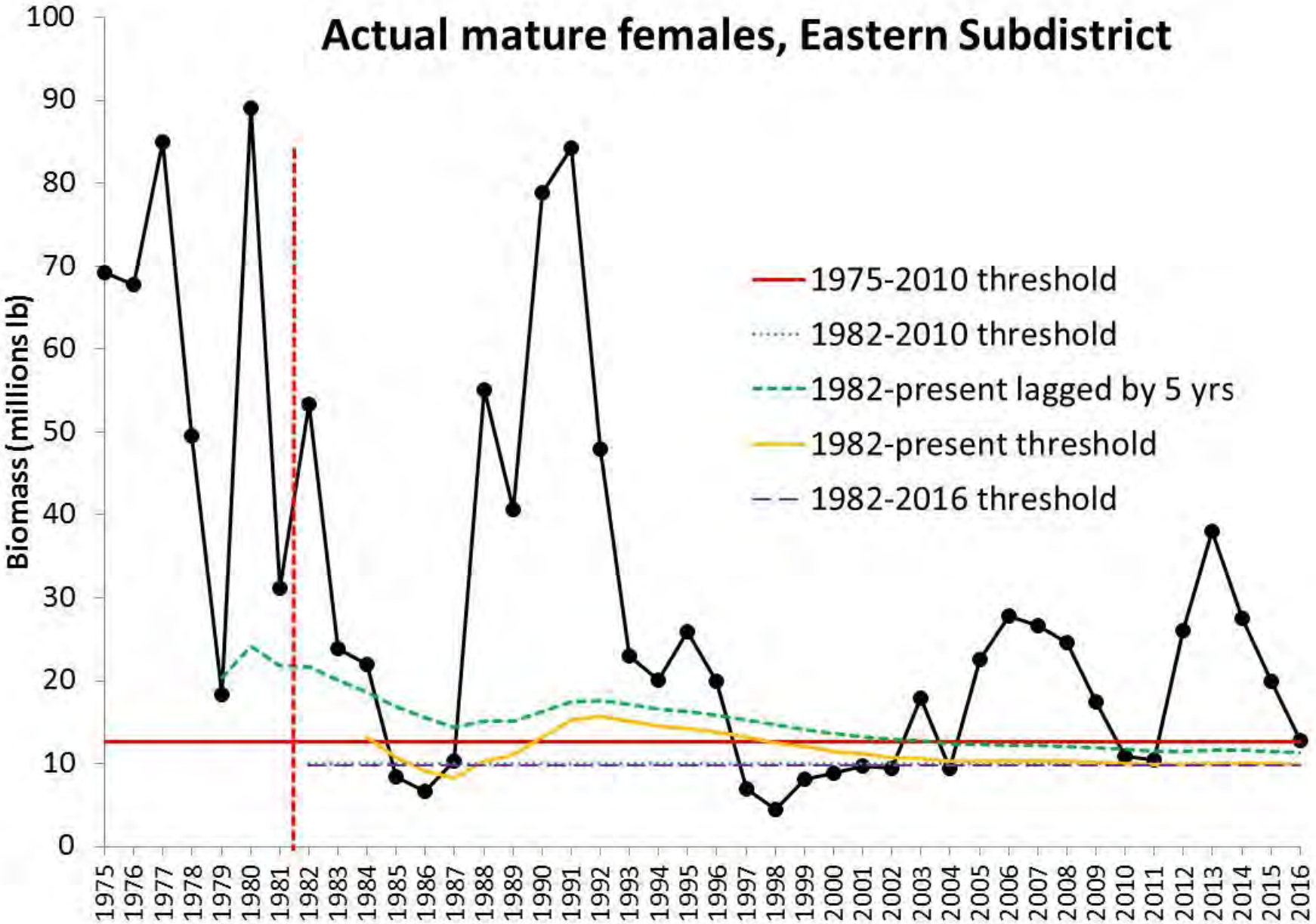
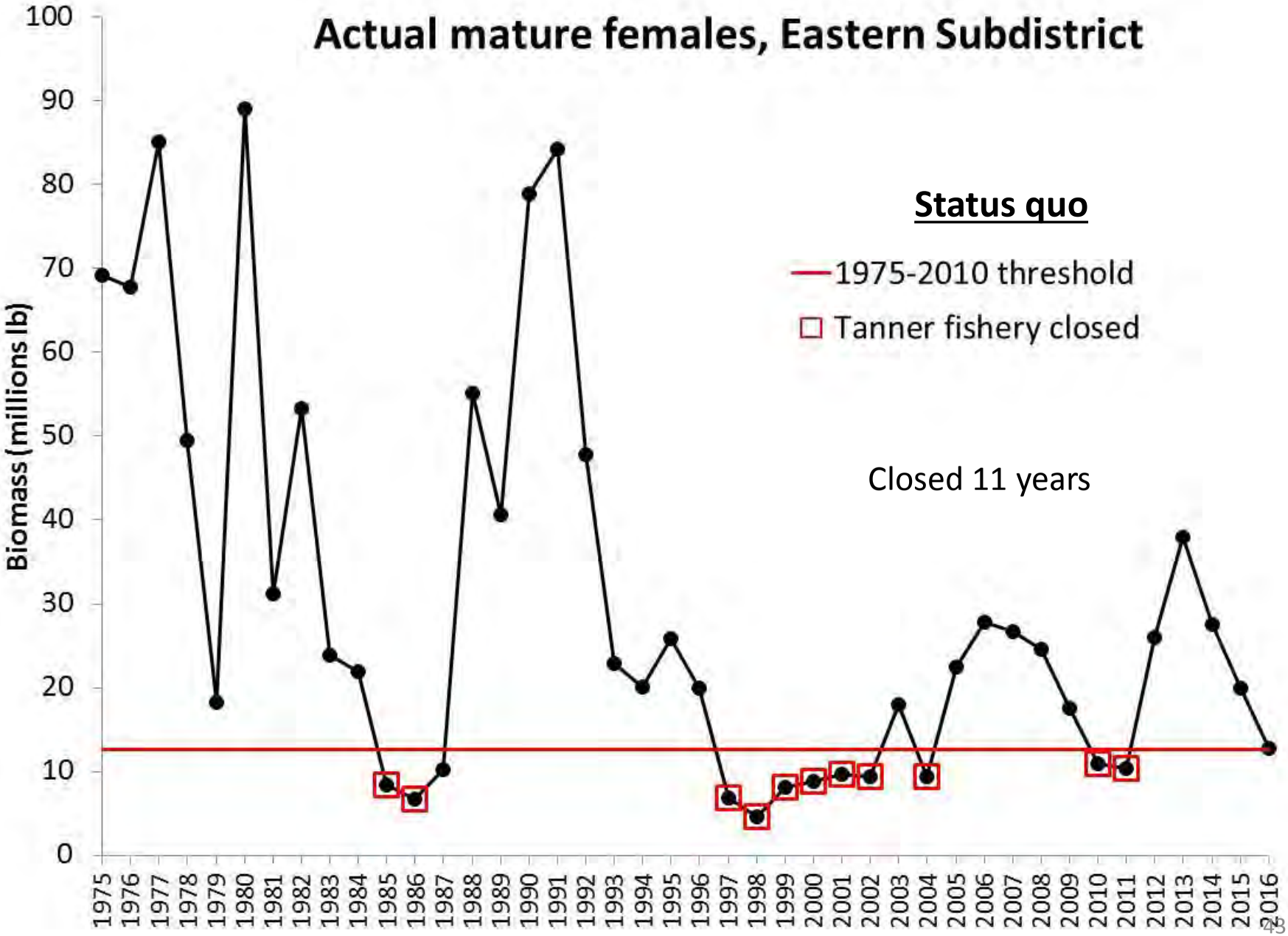
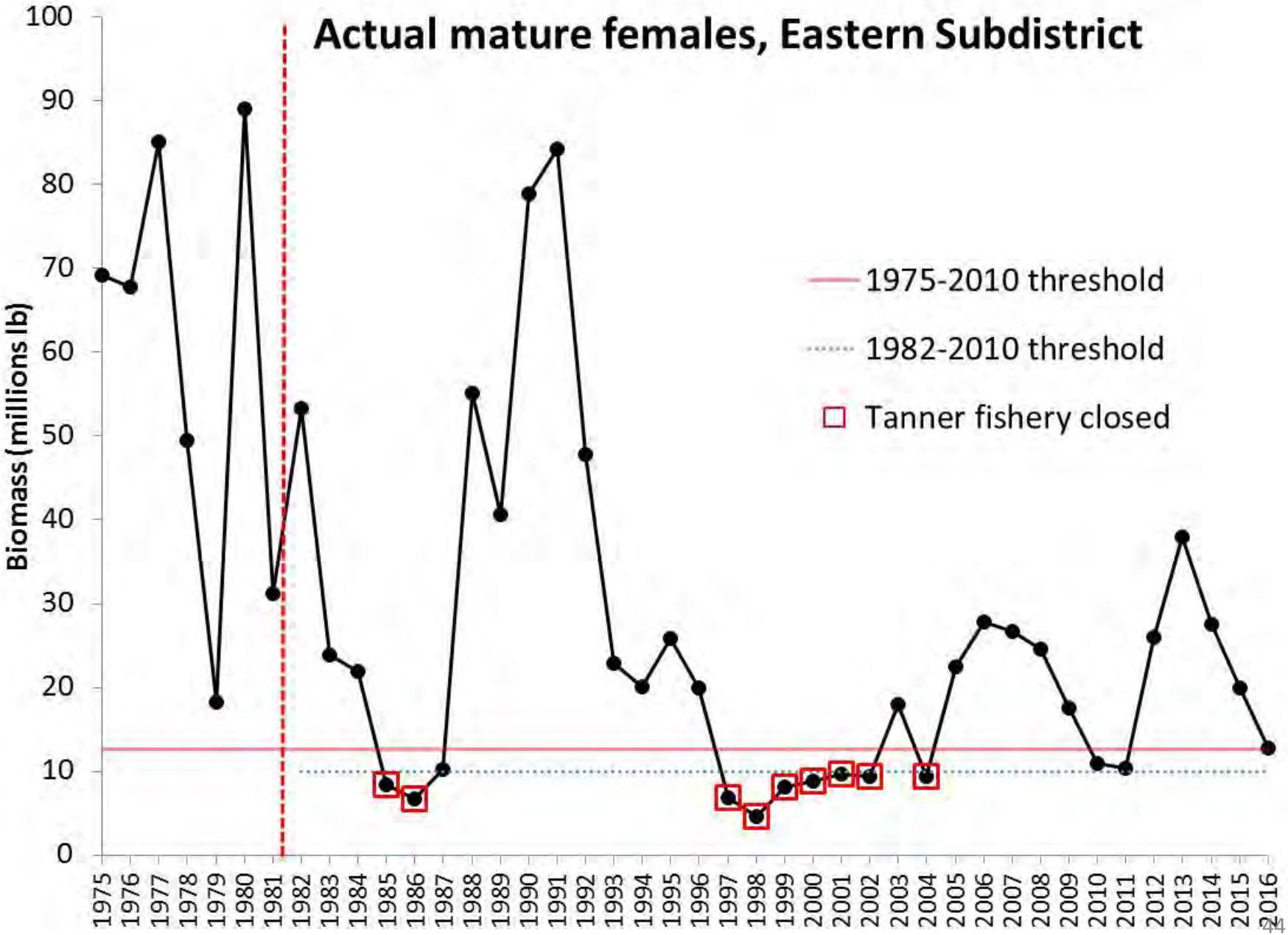
2014
2015
2016
1975-2010 threshold
1982-2010 threshold
1982-present lagged 5 yrs
1982-present threshold
1982-2016 threshold


Actual mature females, Eastern Subdistrict
Biomass (millions lb)
100
90
80
70
60
50
40
30
20
10
0
1975-2010 threshold
1982-2010 threshold
1982-present lagged by 5 yrs
1982-present threshold
1982-2016 threshold
1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016


Actual mature females, Eastern Subdistrict
Biomass (millions lb)
100
90
80
70
60
50
40
30
20
10
0
1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016
Status quo
1975-2010 threshold
Tanner fishery closed
Closed 11 years


Actual mature females, Eastern Subdistrict
Biomass (millions lb)
100
90
80
70
60
50
40
30
20
10
0
1975-2010 threshold
1982-2010 threshold
Tanner fishery closed
1975
1976
1977
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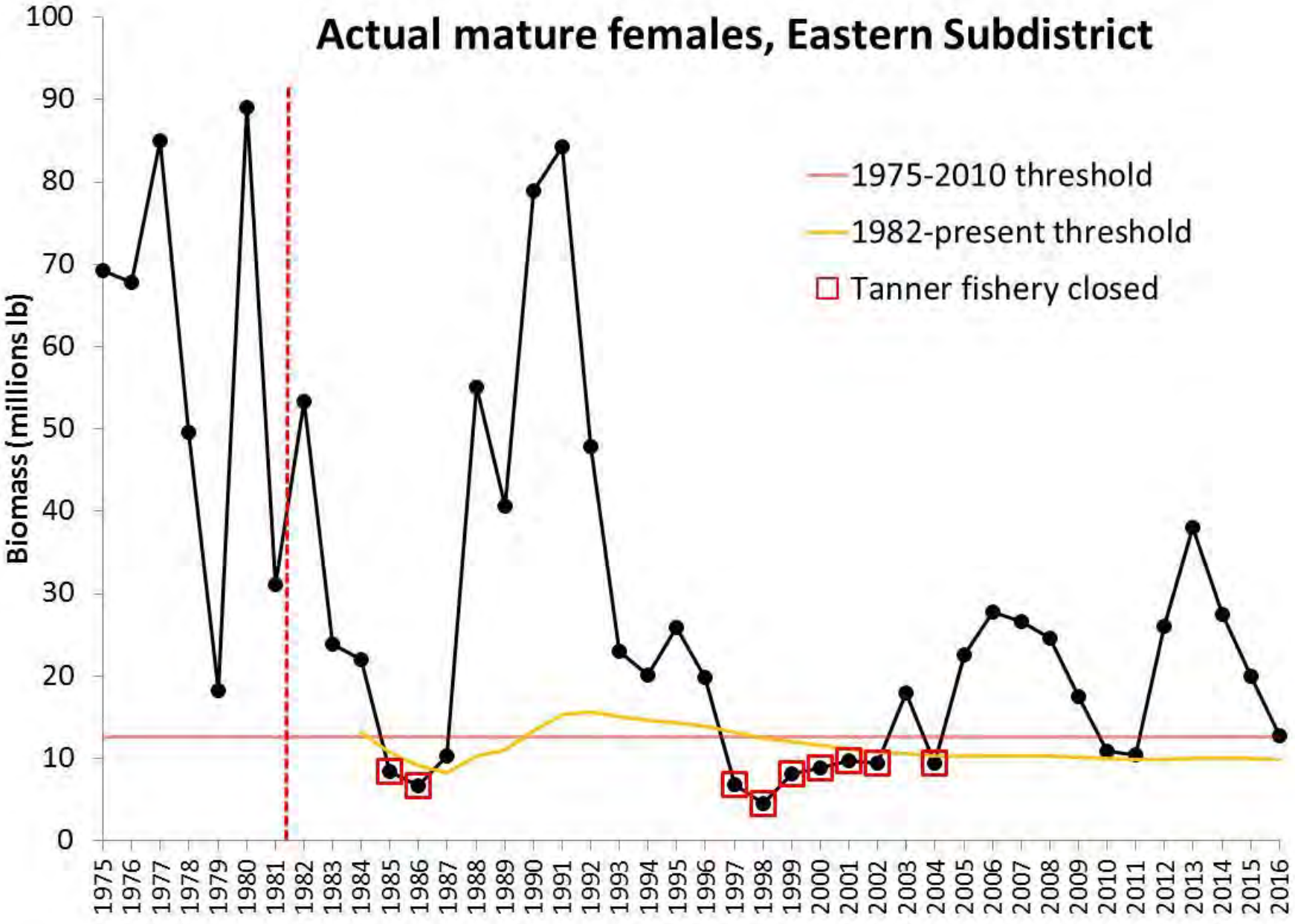
Actual mature females, Eastern Subdistrict
Biomass (millions lb)
100
90
80
70
60
50
40
30
20
10
0
1975-2010 threshold
1982-present threshold
Tanner fishery closed
1975
1976
1977
1978
1979
1980
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1982
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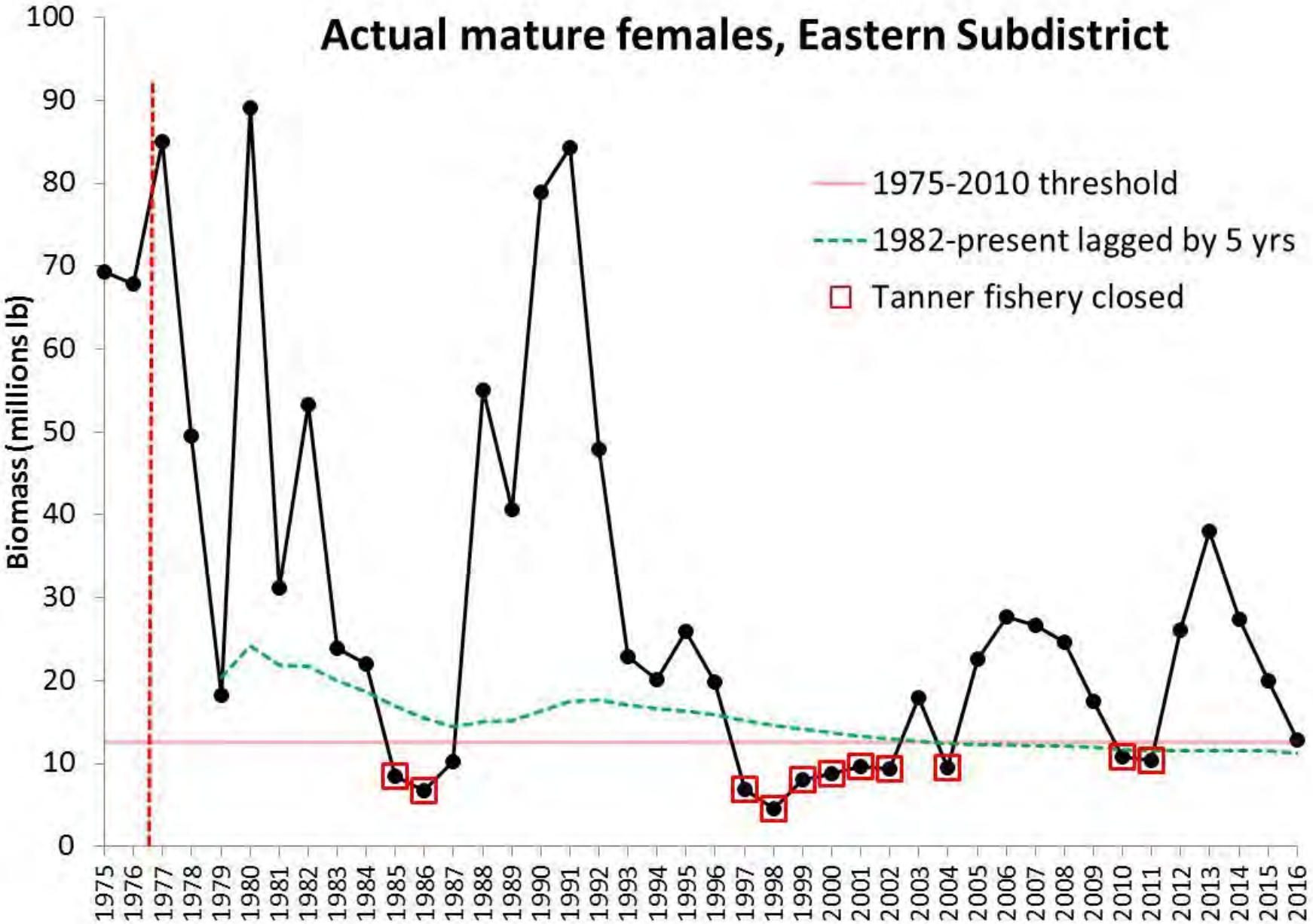
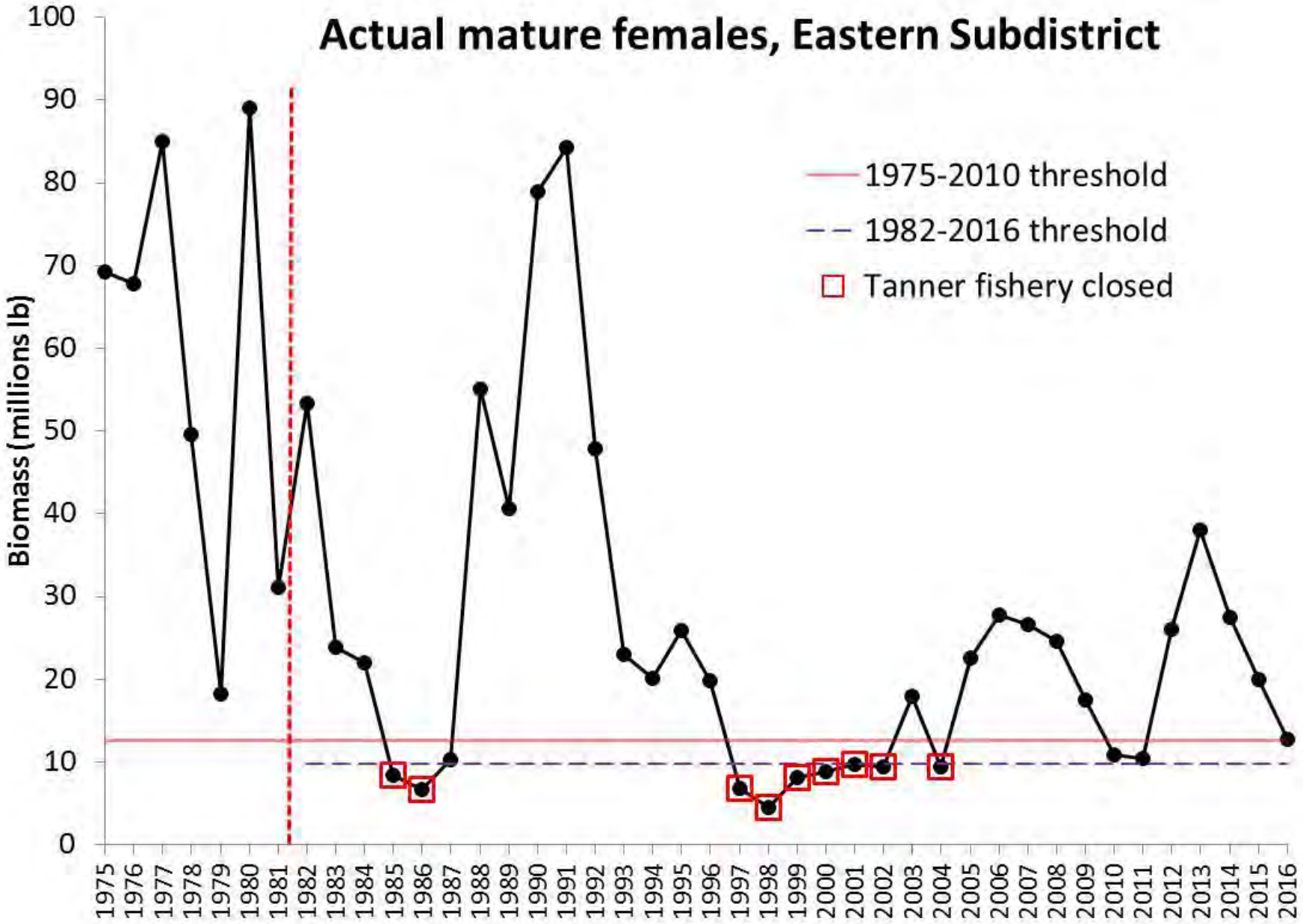
2016


Actual mature females, Eastern Subdistrict
Biomass (millions lb)
100
90
80
70
60
50
40
30
20
10
0
1975-2010 threshold
1982-present lagged by 5 yrs
Tanner fishery closed
1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016


Actual mature females, Eastern Subdistrict
Biomass (millions lb)
100
90
80
70
60
50
40
30
20
10
0
1975-2010 threshold
1982-2016 threshold
Tanner fishery closed
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
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1992
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2014
2015
2016

Year scenarios for mature female threshold consideration

- 1975-2010 (status quo)
- 1982-2010
- 1982-present
- 1977-present (1982-present lagged by 5 yrs)
- 1982-2016

Year scenarios for mature female threshold consideration

- 1975-2010 (status quo)
- 1982-2010
  - effects of the pre-1982 years
- 1982-present
  - Regime shift justification
- 1977-present (1982-present lagged by 5 yrs)
  - Assessment model justification: average recruitment to the model lagged by 5 years
- 1982-2016
  - Regime shift justification
  - Fixed years minimize conservation concern of chasing the threshold

Conservation concern when including the terminal year in a running average:

- When population is in a downward trend, the threshold is lowered slightly each year (i.e., “chasing the threshold”), thereby liberalizing requirements for fishery openings
- Opposite is true in an upward trend: threshold increases creating more conservative requirements
- No state crab harvest strategy uses a running average because of conservation considerations

Exclude 1982-present from consideration

1982-2016 scenario

- Excludes animals alive in pre-1977 regime shift conditions
- Represents “current conditions” but considers most of the time series
  - Optimizes temporal coverage
- Consistent trawl survey net
- Uniform spatial coverage of survey
- Generally consistent with stock assessment model years for average recruitment
- Retrospective analysis: *potentially* reduces number of years fishery is closed
  - Effects of a fishery in years that were historically closed are uncertain
- The fixed time span eliminates the “chasing the threshold” effect

Recommendation:
Use 1982-2016 to calculate female threshold

What About Male TAC Calculations?

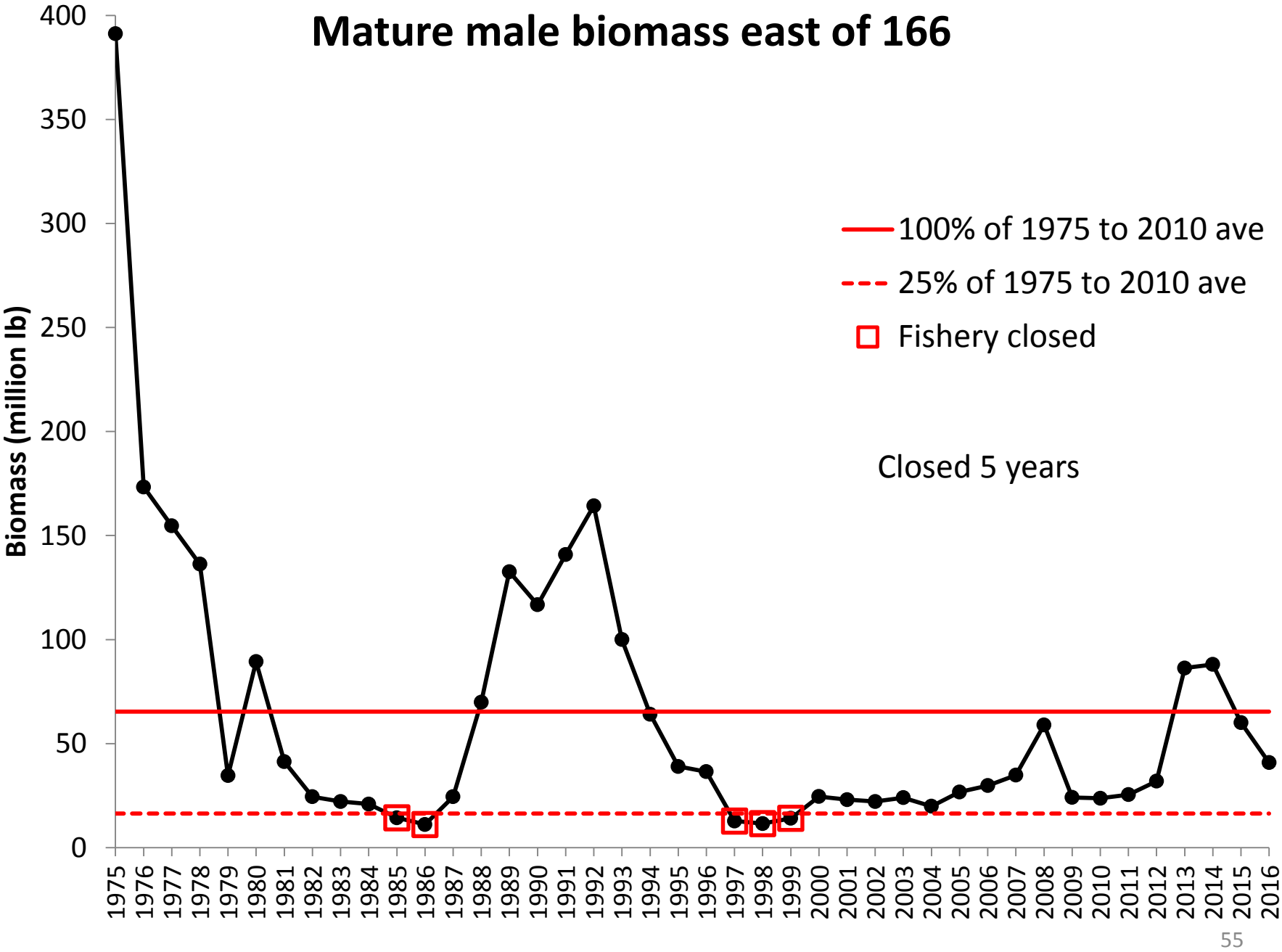
Bering Sea Tanner Crab

State harvest strategy (5 AAC 35.508)

2. If mature female biomass above stock threshold, separate TACs set for Bering Sea District east and west of 166° W long.

A. TAC for area east of 166° W long

- Define:
  - B_E = biomass of mature ♂♂ (≥113 mm CW) east of 166° @ survey
  - $B_{E,AVG}$ = average of the annual B_E's for 1975-2010
  - "$B_{E,AVG}$" is called "$B_{E,(1975\text{-}2010)}$" in 5 AAC 35.508
  - $B_{E,AVG}$ = 65.333-mill lb
    - 2015 revised NMFS area-swept est (value is not in 5 AAC 35.508)
  - $C_{E,MSY}$ = catch biomass of ♂♂ ≥ 127 mm CW (5.0 inches CW) resulting from fishing on mature male biomass in area east of 166° W long. @ time of mating at full-selection F_{MSY} rate (or F_{MSY} proxy)
  - $C_{E,0}$ = biomass of ♂♂ ≥ 127 mm CW (5.0 inches CW) east of 166° W long., discounted by fishery selectivity, that would survive to time of mating with no fishing mortality
    - The abbreviation, "$C_{E,0}$", is not used in 5 AAC 35.508
- **TAC** =
  - 0, if $B_E < 25\%$ of $B_{E,AVG}$
  - $(0.9)x(B_E / B_{E,AVG})xC_{E,MSY}$, if $B_E \geq 25\%$ of $B_{E,AVG}$ and $B_E \leq B_{E,AVG}$
  - $(0.9)xC_{E,MSY}$, if $B_E > B_{E,AVG}$
- **Maximum TAC**: TAC ≤ 50% of $C_{E,0}$
- **Additionally:** If mature female biomass was below stock threshold in previous year, TAC is reduced by ½ of computed


Mature male biomass east of 166
Biomass (million lb)
400
350
300
250
200
150
100
50
0
100% of 1975 to 2010 ave
25% of 1975 to 2010 ave
Fishery closed
Closed 5 years
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
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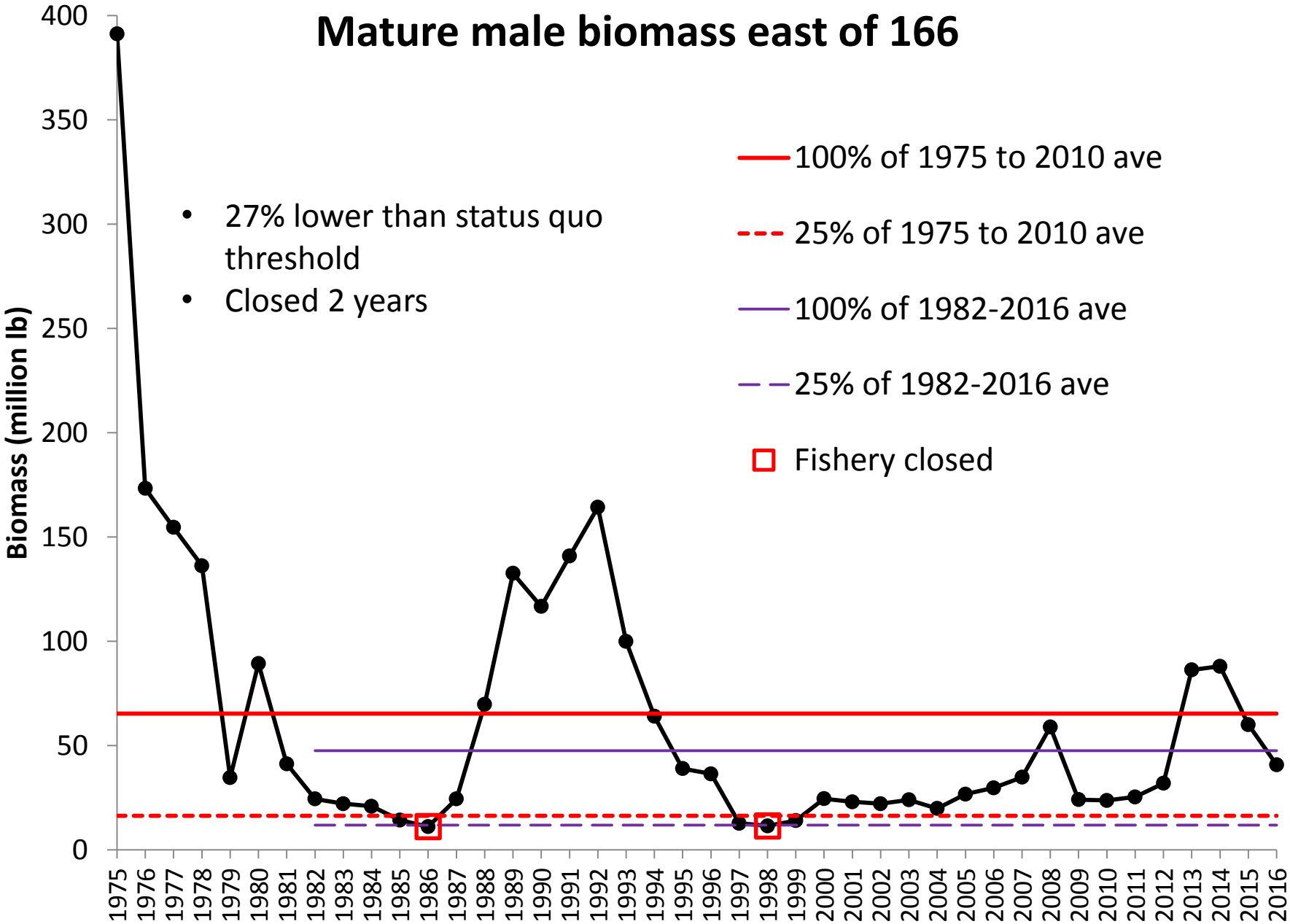
2015
2016

Mature male biomass east of 166



Effects of years on male threshold calculation

- Excluding early years reduces threshold
- Reduced instances of fishery closures
- Lowering thresholds softens regulations, liberalizes fishery (TACs based estimates relative to thresholds)
- Consistency with justification for female years

Recommendation:
Use 1982-2016 to calculate male thresholds

Risks of changing threshold years (males and females)

- Cutting off pre-1982 years lowers thresholds
- Increase risk of overfishing or causing stock to be overfished
  - Male harvest rate depends on thresholds

Females west of 173° W long.

Board Generated Proposal

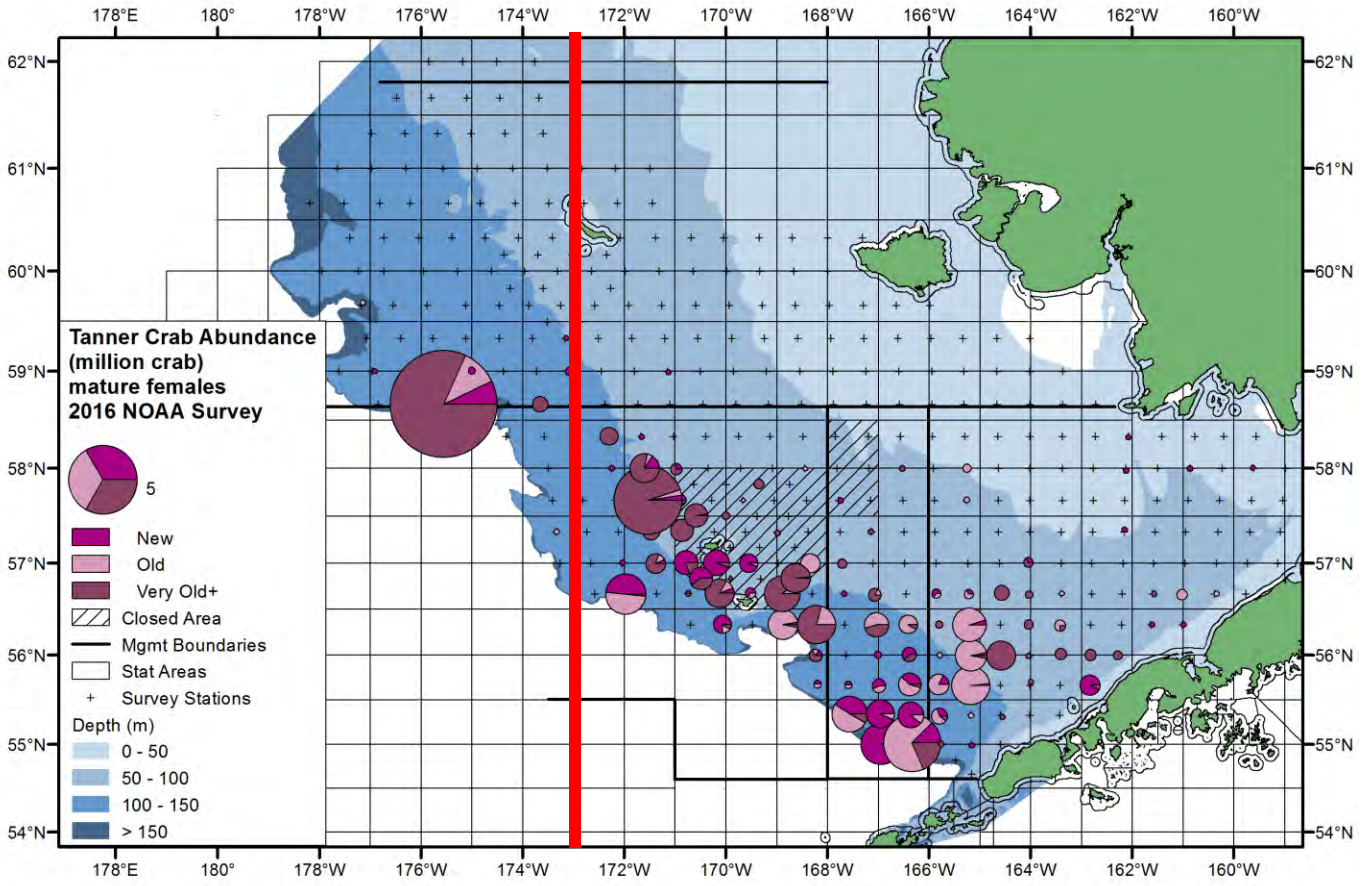
A. Criteria used to determine mature female Tanner crab (size-cut vs actual);
B. Area used to estimate female biomass (i.e., west of 173° W. long);
C. Years used to estimate long-term average mature female biomass;
D. Utility of ½ TAC penalty: Provision that TAC is reduced 50% in any year succeeding a year in which the mature female Tanner crab biomass falls below threshold.

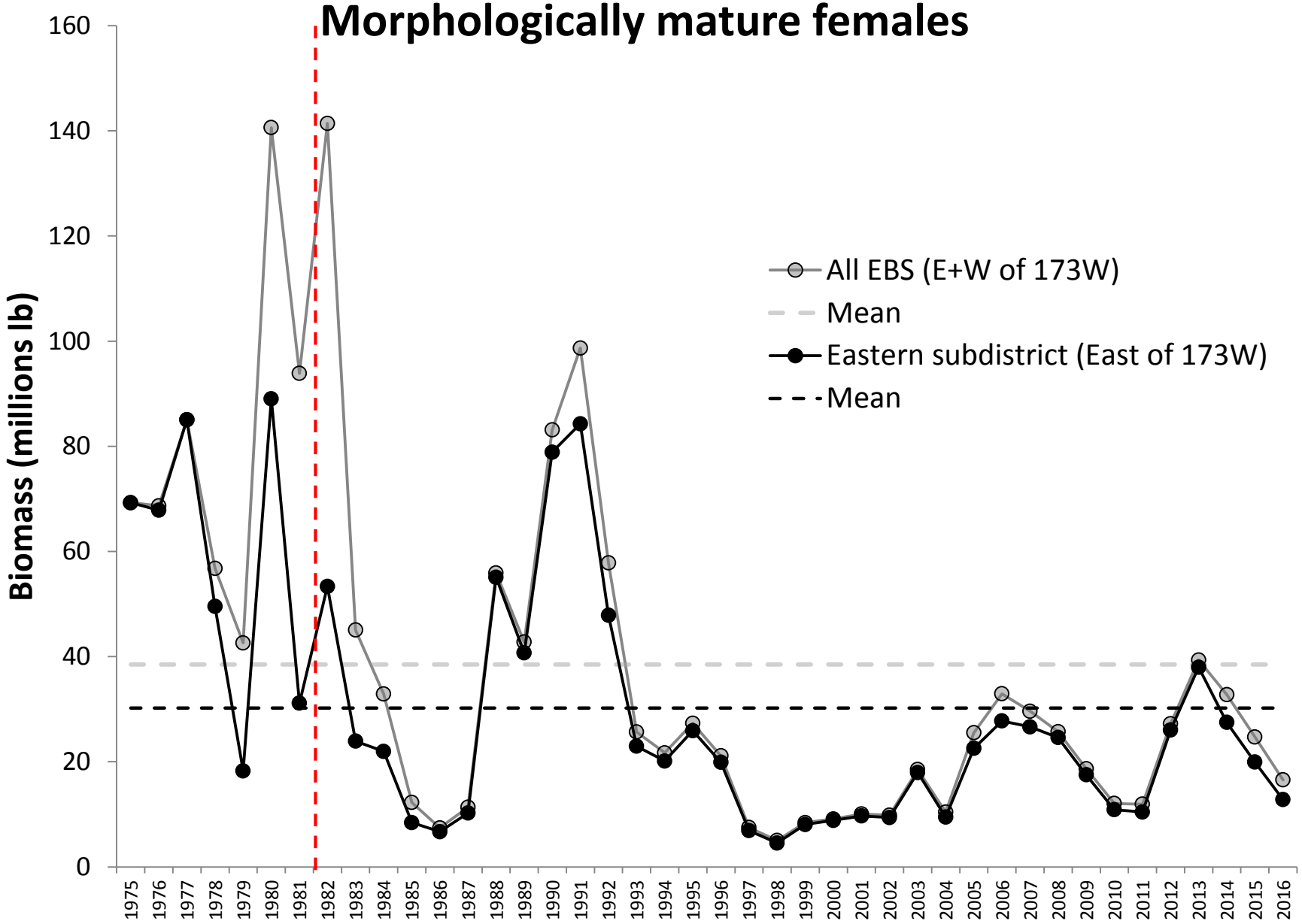
<u>Other Elements of Interest</u>

E. Alternatives to a single open/close threshold (i.e., alternatives to the on/off switch to facilitate flexibility)
F. Consider upper male threshold to determine harvestable surplus

Eastern Subdistrict

Some mature females west of 173° W not included in threshold calculation.




Morphologically mature females
Biomass (millions lb)
160
140
120
100
80
60
40
20
0
All EBS (E+W of 173W)
Mean
Eastern subdistrict (East of 173W)
Mean
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
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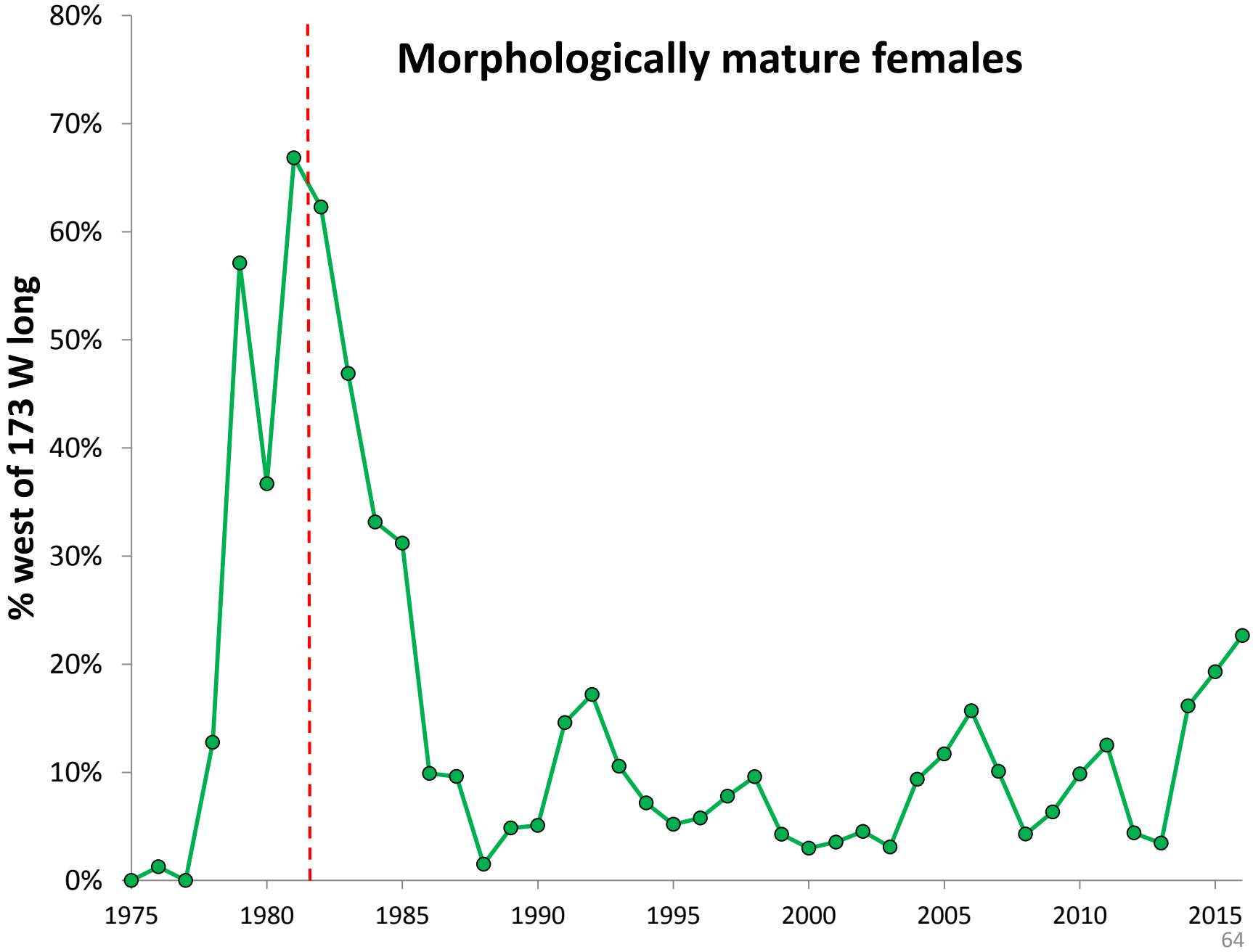
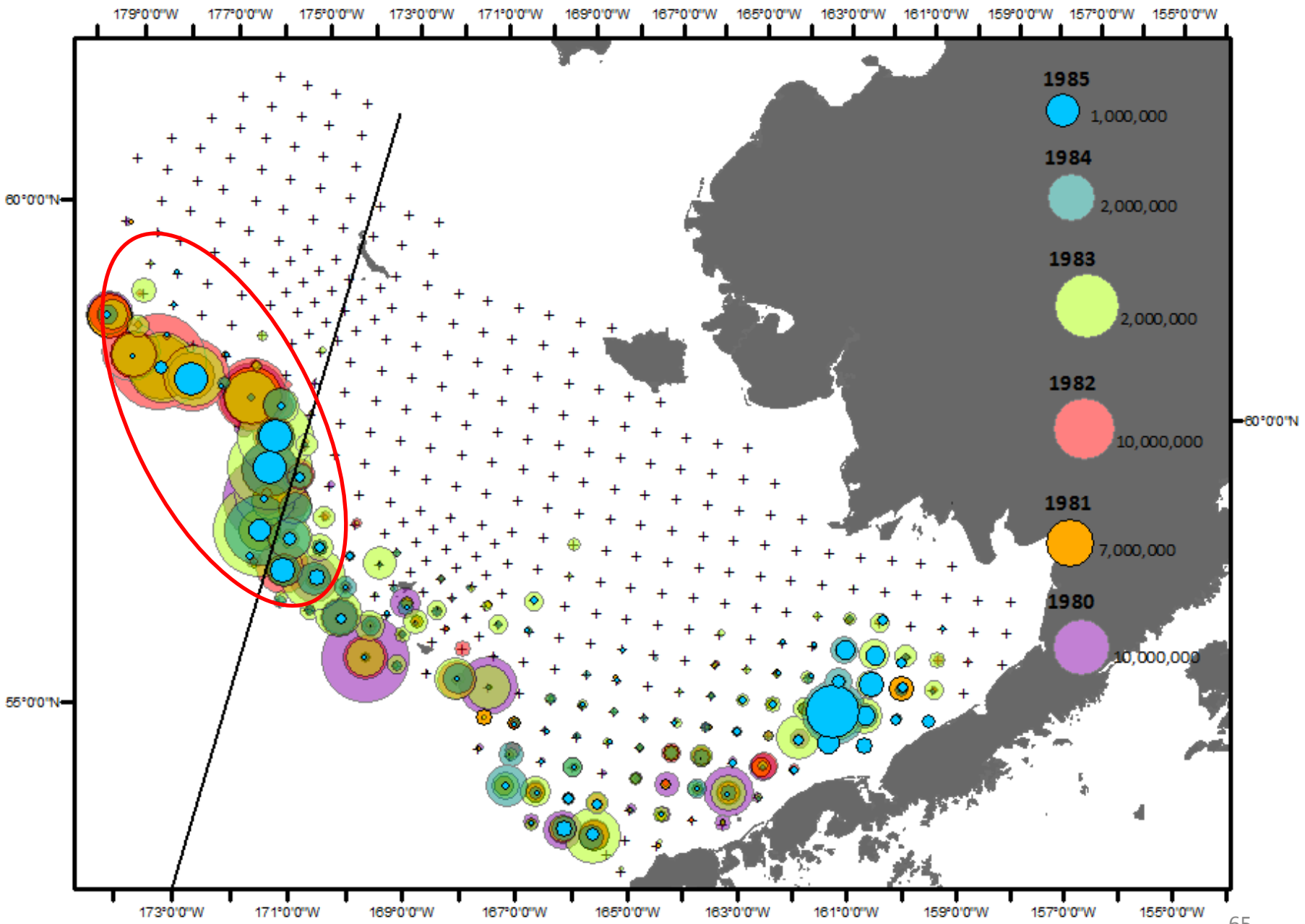
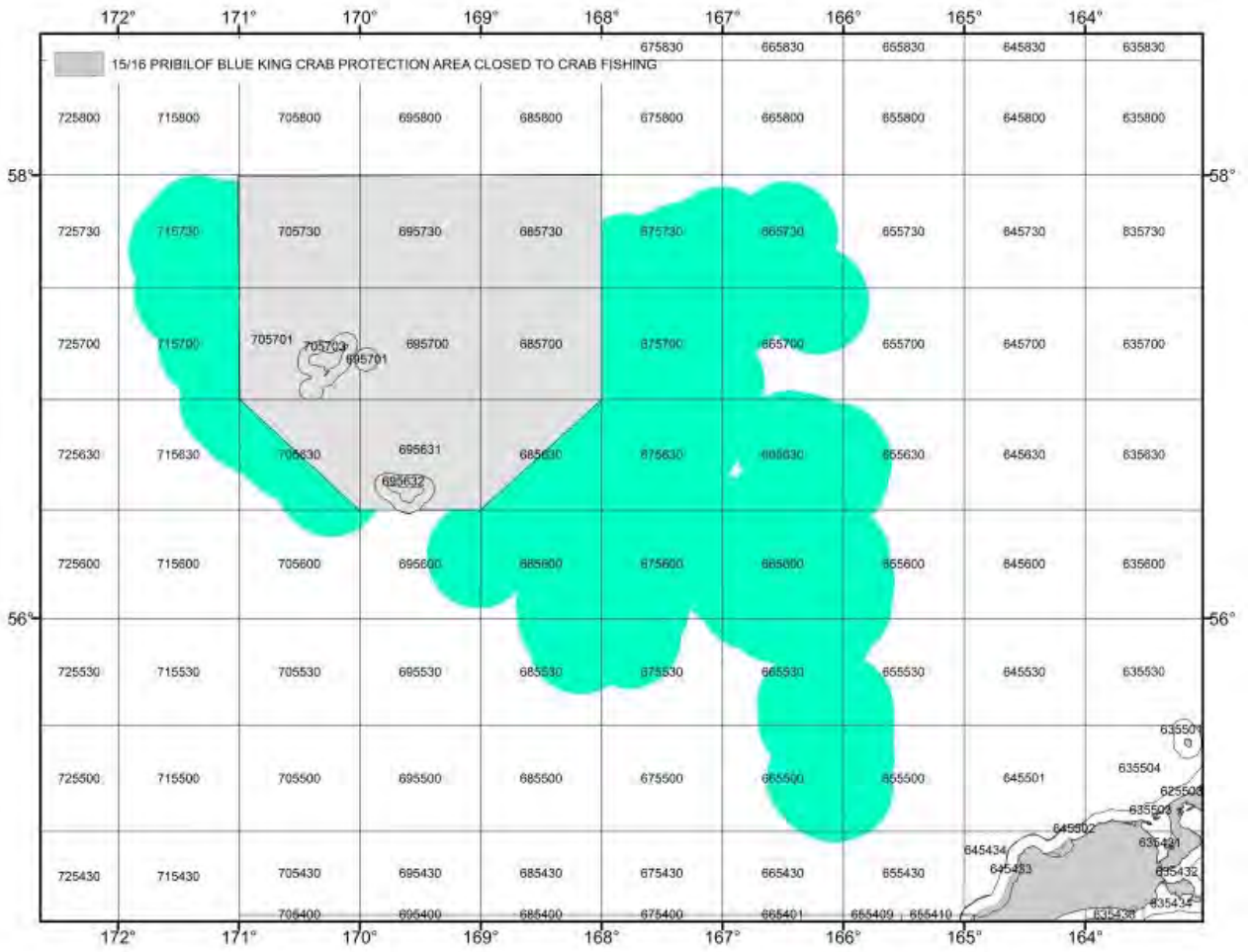

Morphologically mature females
% west of 173 W long
80%
70%
60%
50%
40%
30%
20%
10%
0%
1975
1980
1985
1990
1995
2000
2005
2010
2015

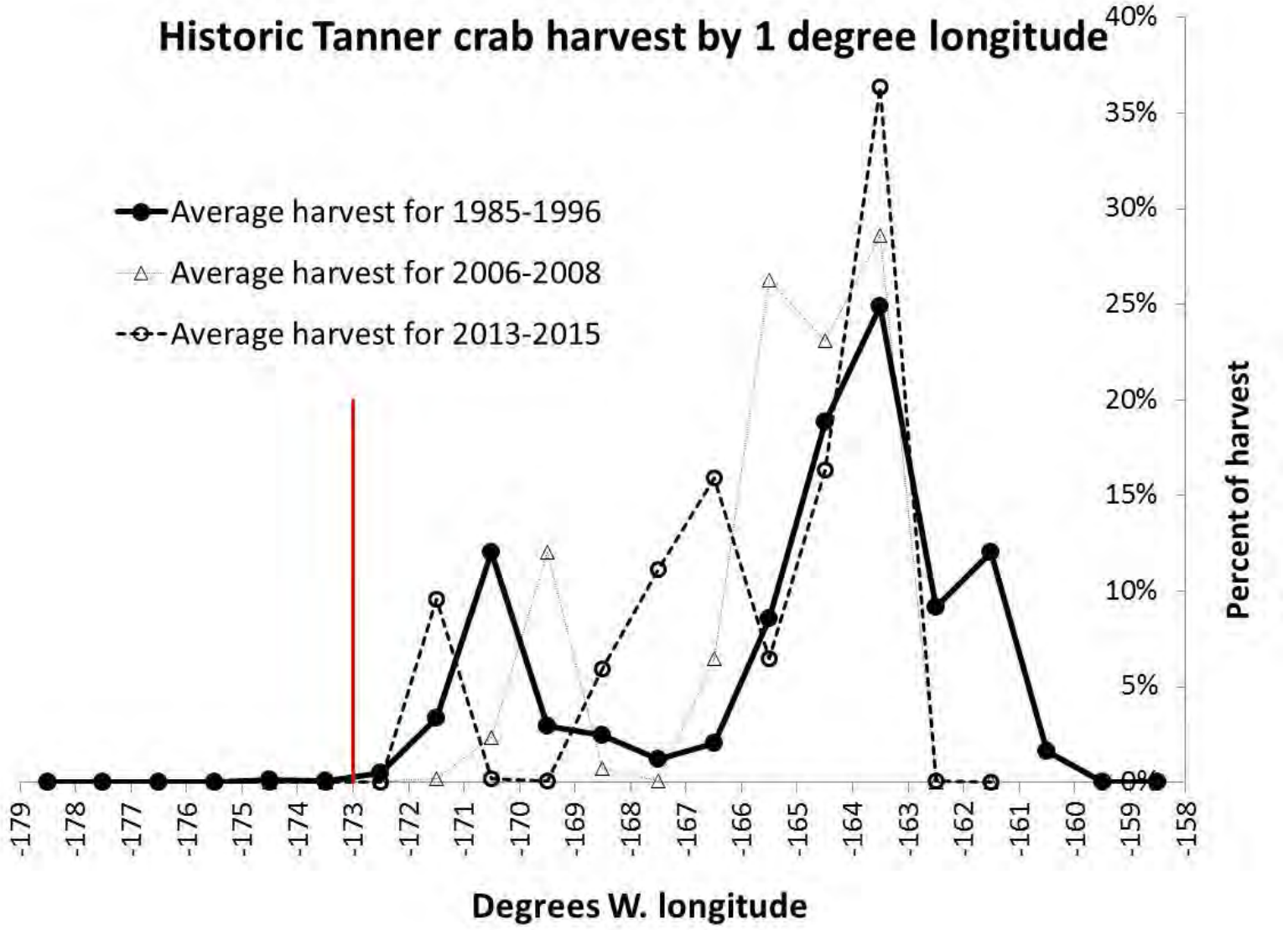

179°0'0"W
177°0'0"W
175°0'0"W
173°0'0"W
171°0'0"W
169°0'0"W
167°0'0"W
165°0'0"W
163°0'0"W
161°0'0"W
159°0'0"W
157°0'0"W
155°0'0"W
60°0'0"N
55°0'0"N
1985
1,000,000
1984
2,000,000
1983
2,000,000
1982
10,000,000
1981
7,000,000
1980
10,000,000

What is the fished portion of the population?

Observer pot location 2015/16 WBT fishery



What is the fished portion of the population?



Are females west of 173 W long contributing to the fished population?

- Actively mating in the fished portion of population?
- Are larvae advected to, and settle in, fished portion of population?

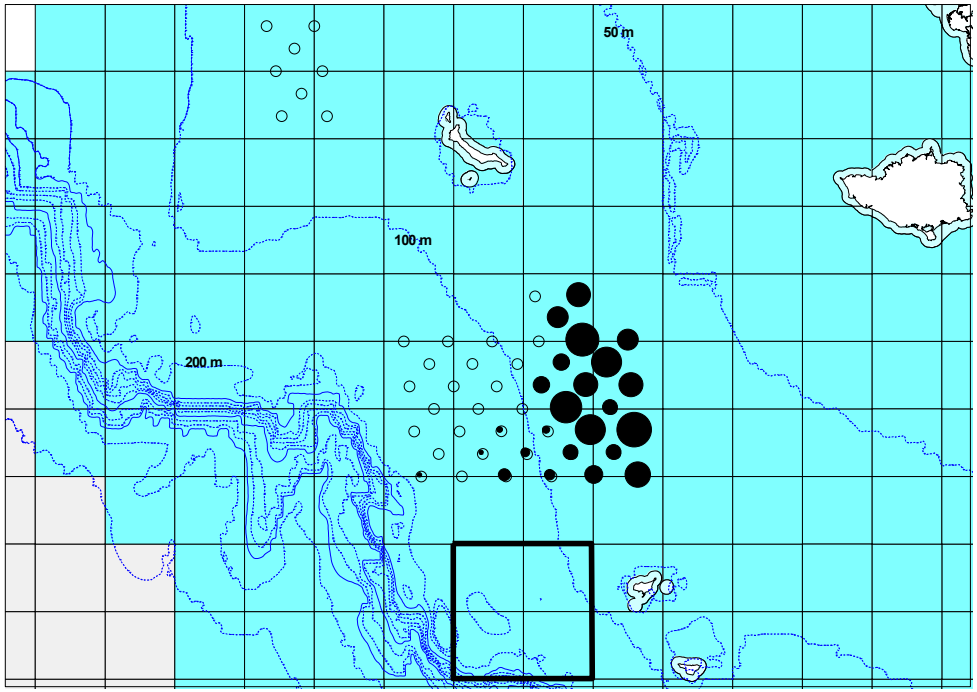
Juvenile and adult migration

- Capable of moving to the area east of 173 W
- Are they? *Unknown*
  - Size at maturity: no strong evidence to suggest separate subregion west of 173 W
  - Tagging studies: little to no information about female movement

What we know about snow crab

Tagging study: 4 inch males (Pengilly, Slater, MacTavish 2009)

- Some 4 inch male crabs move south (~90 miles) between the summer NOAA survey and the following fishery (Jan-May).



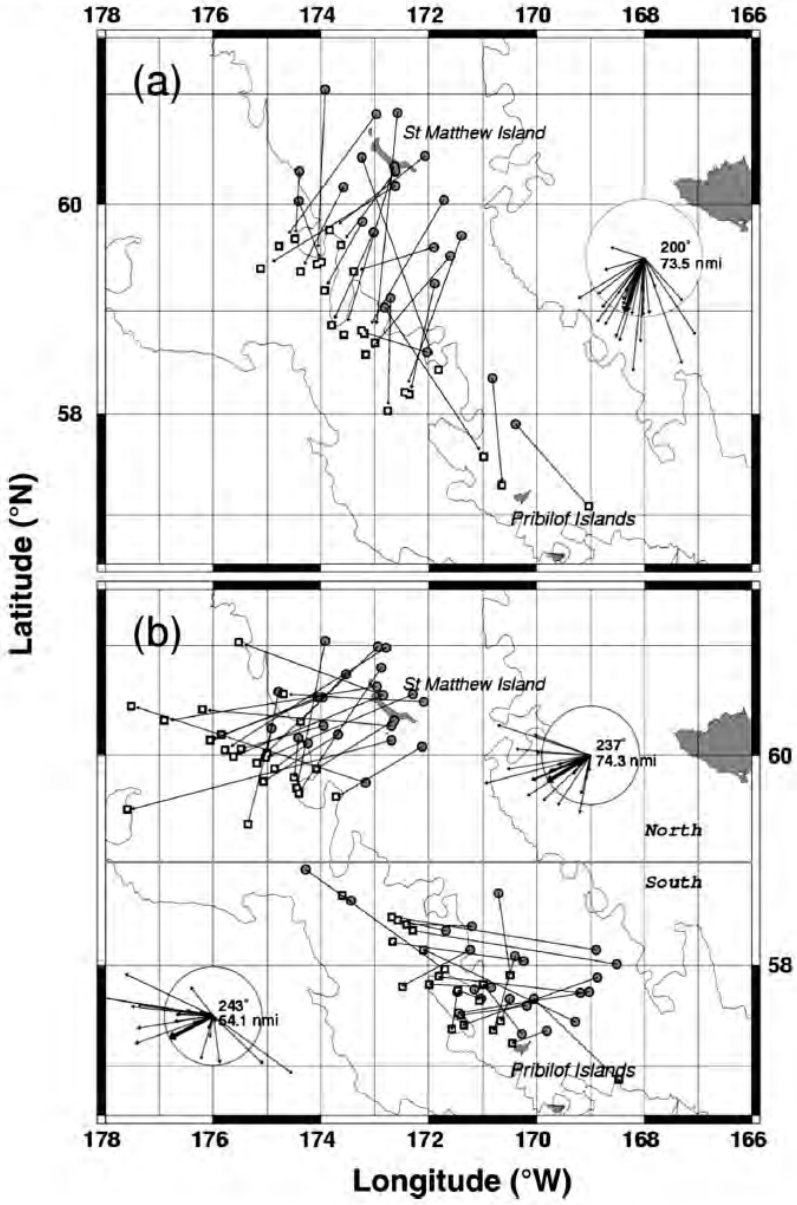
Percent of tagged crabs recovered by station:

- Largest circle = 6.9%
  - 2.6% of crabs tagged in South mid-shelf
  - 0.2% of crabs tagged in South outer-shelf
  - 0% of crabs tagged in North block

What about female snow crab?

- Ontogenetic migration of cohorts south-west towards shelf edge (longer-term).
- Likely influenced by environmental variables.
- What about seasonal migrations?: *Unknown*

Fig. 6. Centroids of abundance of mature snow crab (*Chionoecetes opilio*) females in SCI 2 (circles) and SCI 3 (squares) by pseudo-cohort. Thin arrows connecting centroids represent average annual migration (distance and azimuth). Inset circles summarize the migration pattern; the thick arrows represent average migration. (*a*) Centroids and migration computed for the entire Central Shelf; (*b*) Central Shelf divided into northern and southern sectors at 59°N.



Ernst et al., 2005)

Are females west of 173 W long contributing to the fished population?

Larval advection

- Larvae spend months in water column before settling on bottom
- Capable of being advected distances up to hundreds of km
- Larvae capable of drifting to the area east of 173 W
- Are they? *Unknown*
  - Hydrodynamic models suggest larvae generally advected northwest, with limited drift to the east

Should females west of 173 W long. be included in threshold calculation?

Best science:

- Adult crabs capable of migrating east of boundary, but it is unclear if they are
- Larvae are likely not drifting to east of 173 W long.
- Spatial distribution of mature females shifts over time
- Effects of including females west of 173 W long. unclear, but no strong evidence to suggest this would be a conservation concern
- Would address large-scale population spatial shifts by including all females

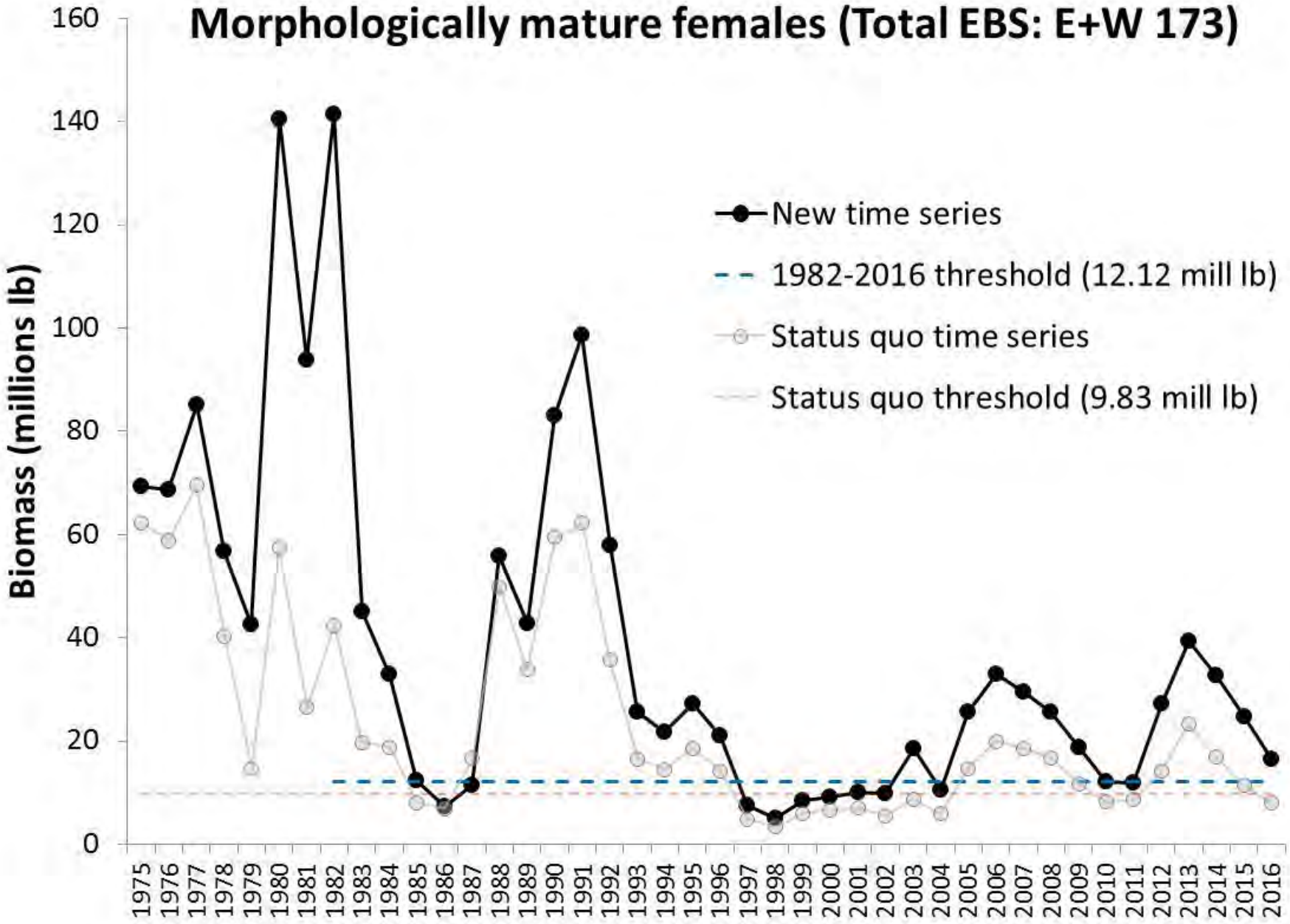
Management:

- Male threshold incorporates crabs west of 173 W long.
- Including females would be consistent with male portion of harvest strategy

Recommendation:
Include females west of 173° W long in threshold calculation

ADF&G recommended mature female threshold calculations

A. **Define maturity based on morphology of abdominal flap (actual maturity)**
   - Increases absolute biomass estimates, but has little effect on relative trends
B. **Include females west of 173° W long**
   - Increases threshold because of increased relative biomass in early 1980s
C. **Recommended years: 1982-2016**
   - Lowers threshold by excluding early years of high biomass


Morphologically mature females (Total EBS: E+W 173)
Biomass (millions lb)
160
140
120
100
80
60
40
20
0
New time series
1982-2016 threshold (12.12 mill lb)
Status quo time series
Status quo threshold (9.83 mill lb)
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
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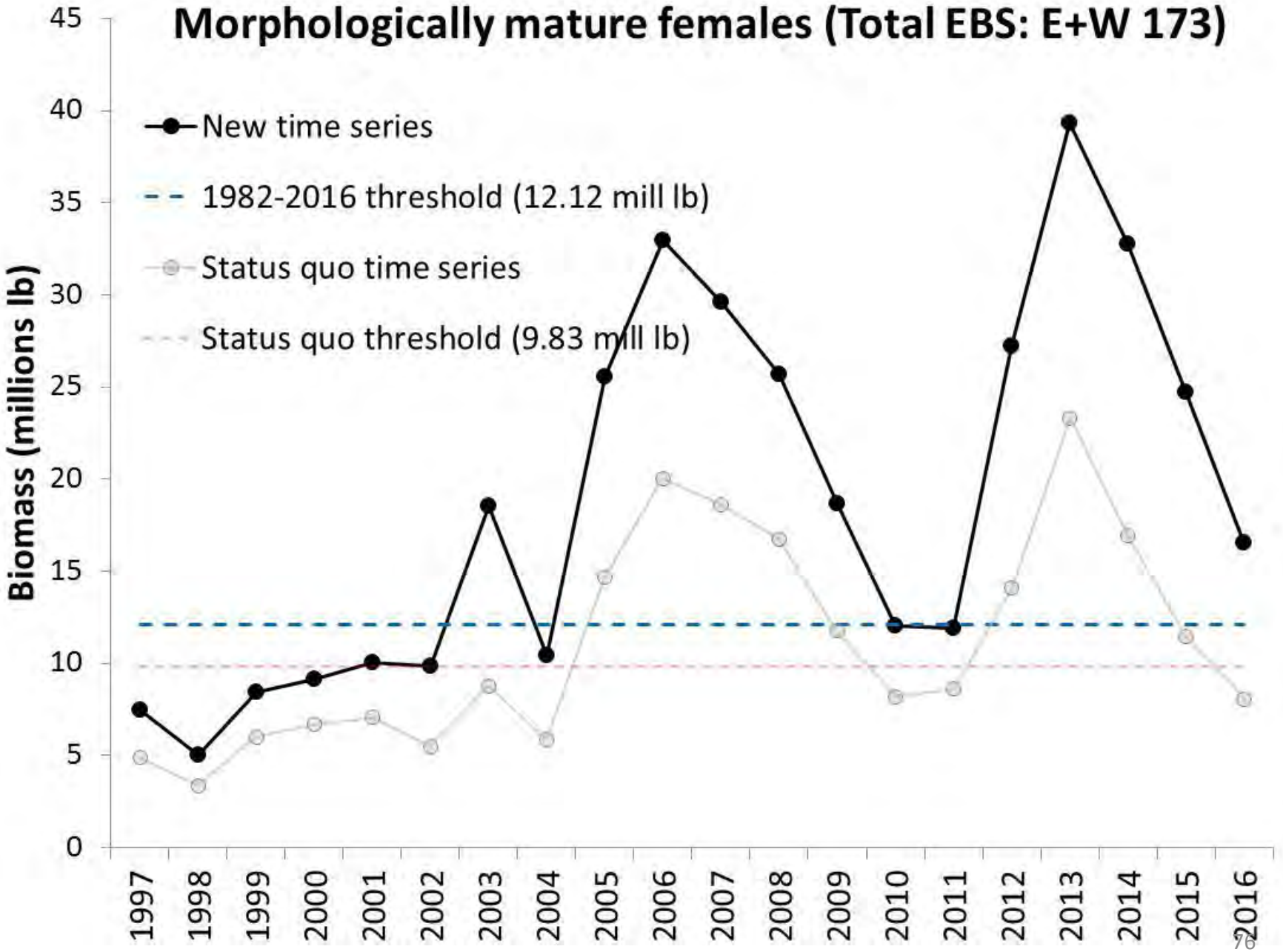
2016


Morphologically mature females (Total EBS: E+W 173)
New time series
1982-2016 threshold (12.12 mill lb)
Status quo time series
Status quo threshold (9.83 mill lb)
Biomass (millions lb)
0
5
10
15
20
25
30
35
40
45
1997
1998
1999
2000
2001
2002
2003
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2011
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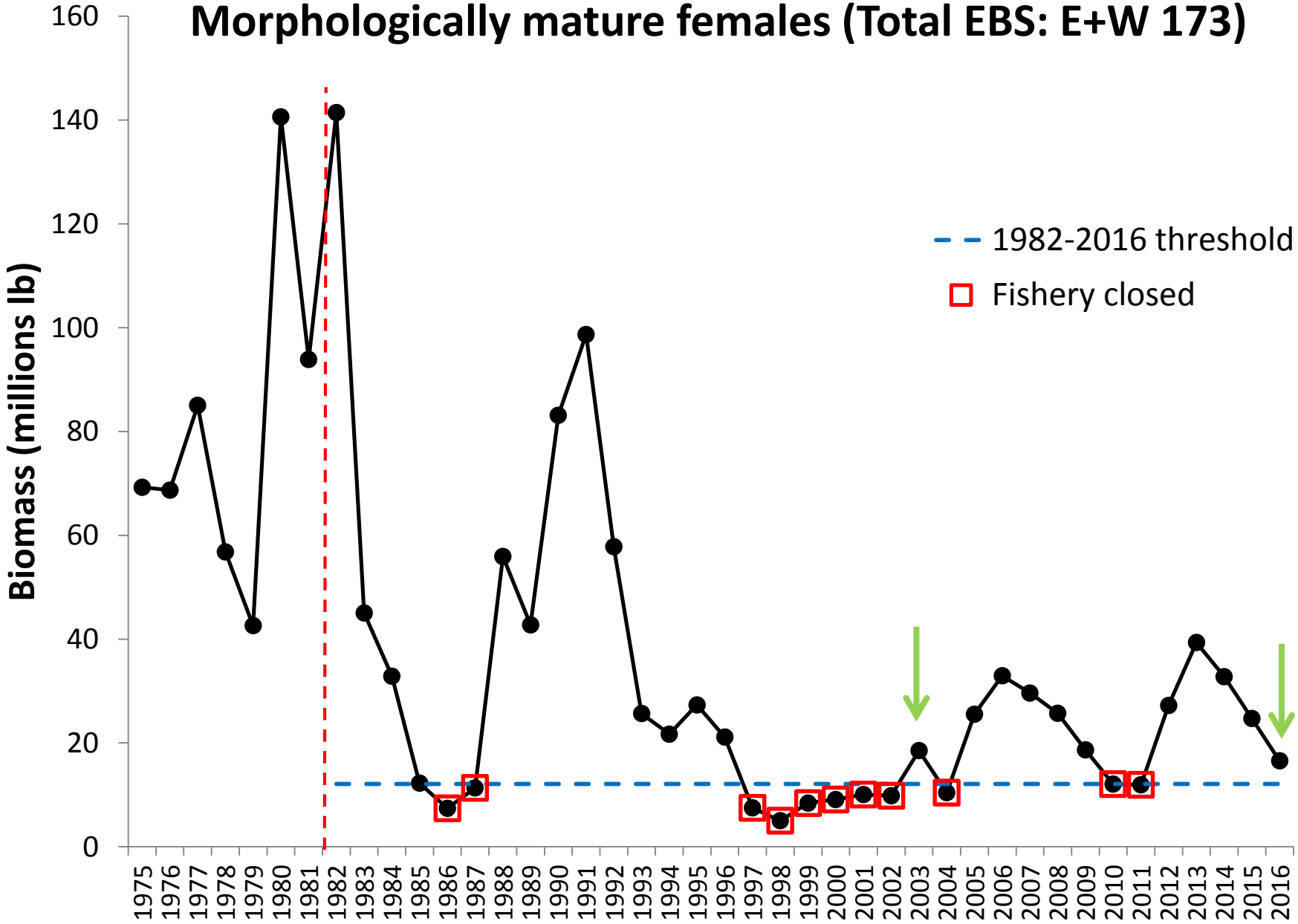
2016


Morphologically mature females (Total EBS: E+W 173)
Biomass (millions lb)
160
140
120
100
80
60
40
20
0
1982-2016 threshold
Fishery closed
1975
1976
1977
1978
1979
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2014
2015
2016

Board Generated Proposal

A. Criteria used to determine mature female Tanner crab (size-cut vs actual);
B. Area used to estimate female biomass (i.e., west of 173° W. long);
C. Years used to estimate long-term average mature female biomass;
D. Utility of ½ TAC penalty: Provision that TAC is reduced 50% in any year succeeding a year in which the mature female Tanner crab biomass falls below threshold.

<u>Other Elements of Interest</u>

E. Alternatives to a single open/close threshold (i.e., alternatives to the on/off switch to facilitate flexibility)
F. Consider upper male threshold to determine harvestable surplus

Utility of TAC penalty

TAC is reduced 50% of calculated value in any year succeeding a year in which the mature female Tanner crab biomass falls below 40% of its long term average.

Precautionary measure:

1. Provides a buffer against the effect of erroneously determining the stock to be above threshold due to random survey error.
2. Due to the lag in maturation of males behind females, the ratio of preferred-sized legal male crab to mature male crab is likely to be low in the first year that the stock is above threshold. This provision protects against a high harvest rate on preferred-sized legal males that could occur under such conditions.

TAC ½ penalty revisited: still has utility

Precautionary measure:

1. Provides a buffer against the effect of erroneously determining the stock to be above threshold due to random survey error.
   - Using model estimates and/or threshold alternatives would address this concern.
2. Due to the lag in maturation of males behind females, the ratio of preferred-sized legal male crab to mature male crab is likely to be low in the first year that the stock is above female threshold.
   - By reducing harvest on legal males, this provision optimizes opportunities for newly recruited females to mate with what is left of the most reproductively viable (large, competitively dominant) males.
   - Still has utility until a more developed alternative to the female threshold is established.

Is the 50% rate still appropriate?

- Difficult to assess suitability of 50% reduction rate
- Precautionary measure
- No data to inform a more suitable reduction rate alternative

Recommendation:
Retain 50% TAC reduction rule

ADF&G recommendations for BGP

A. **Define maturity based on morphology of abdominal flap (actual maturity)**
   - Increases absolute biomass estimates, but has little effect on relative trends
B. **Include females west of 173° W long**
   - Increases threshold because of increased relative biomass in early 1980s
C. **Recommended years: 1982-2016**
   - Lowers threshold by excluding early years of high biomass
D. **Retain 50% TAC reduction rule** in subsequent year, to preserve some of the large males for mating

Intermission

Future Harvest Strategy Improvements

E. Alternatives to a single open/close threshold (i.e., alternatives to the on/off switch to facilitate flexibility)

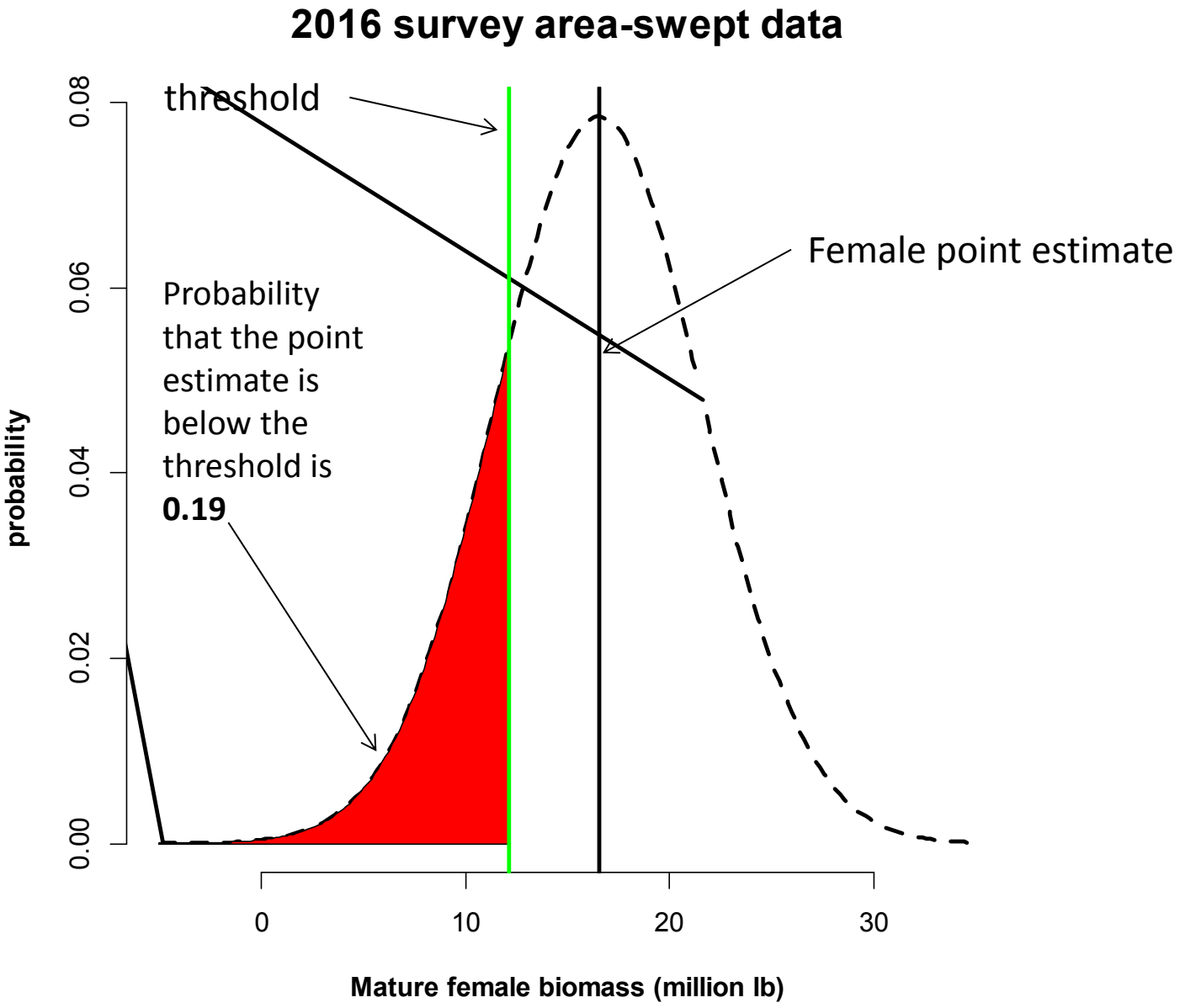
– Is this appropriate, and what are the risks?

F. Upper male threshold to determine harvestable surplus

– How can we define “harvestable surplus” of males?

Female threshold is a “bright line” in the current regulations.

- Is this appropriate?
- Should we consider an alternative that is “less bright”, and/or dims the “on/off switch”?
- Should population variance be considered?
  - Modeling…..


2016 survey area-swept data
threshold
Female point estimate
Probability that the point estimate is below the threshold is 0.19
probability
0.00
0.02
0.04
0.06
0.08
0
10
20
30
Mature female biomass (million lb)

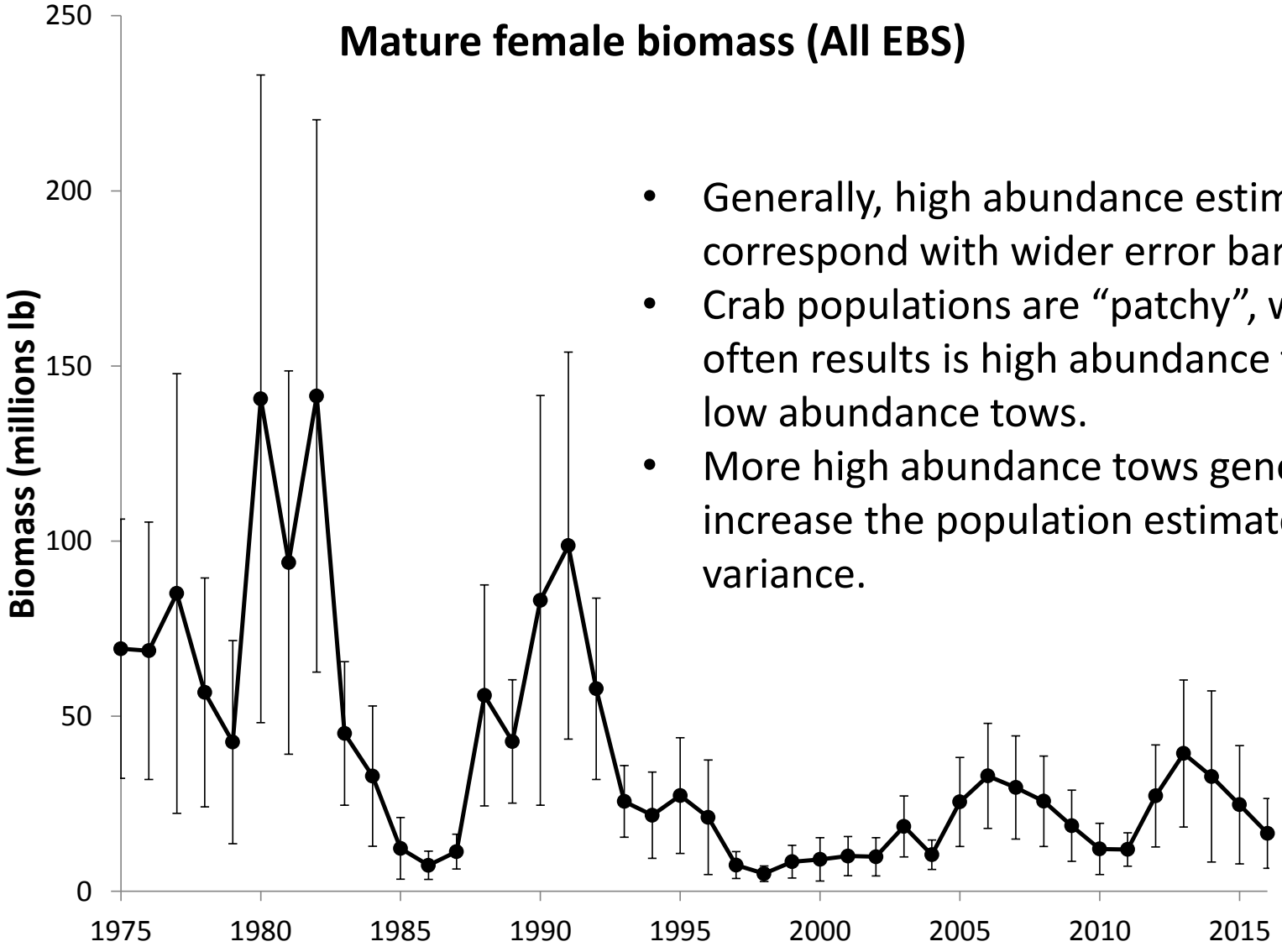
Stock Assessment Models

- Used in federal assessment process to determine OFL and ABC
- Models use best science and account for survey variance, selectivity, maturity, growth, natural mortality, fishery catch, etc……It smooths the data

Three sets of estimates to consider,

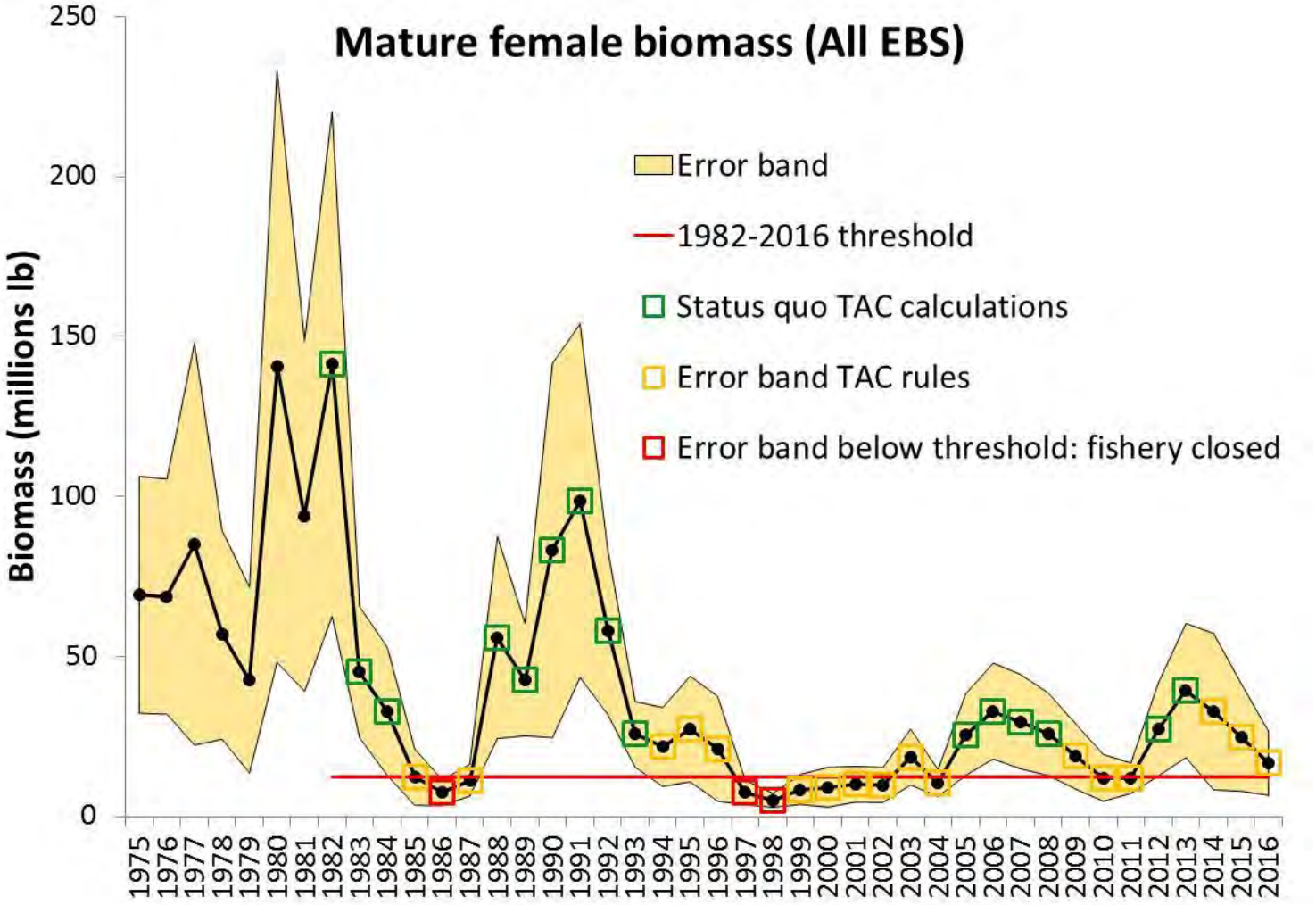
1. **"Observed" estimates (area-swept from NOAA survey**)…….the dots
2. **Model "survey" estimates**…….the fitted line: assumes that **not** all crabs in the line of the trawl survey net are caught.
3. **Model "population" estimates**…….the fitted line that accounts for survey selectivity (Q): estimates what the population is if all crabs in the line of the trawl survey were caught.

Incorporating variance of the survey area-swept point estimates



- Generally, high abundance estimates correspond with wider error bars.
- Crab populations are “patchy”, which often results is high abundance tows and low abundance tows.
- More high abundance tows generally increase the population estimate AND variance.

Incorporating variance of the survey area-swept point estimates



How would an area-swept error band interact with TAC setting?

- **Below threshold**: fishery closed
- **Within error band**: Allows fishery **IF**,

  B/B_{MSY} for mature males is above 100%

  Then, **TAC = $(B/B_{AVG} - 1) \times (0.9) \times C_{MSY}$, OR,**

  TAC = $(0.9) \times C_{MSY}$, whichever is less

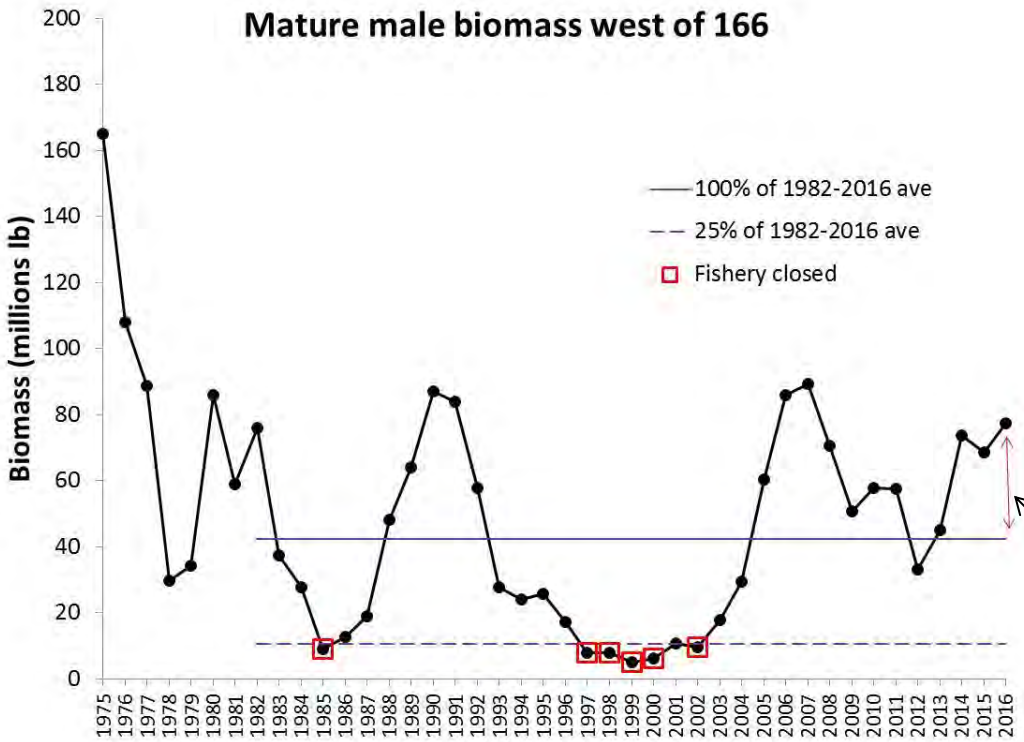
- **Above threshold**: status quo TAC calculations

  If B/B_{MSY} is below 25%, TAC = 0

  If B/B_{MSY} is between 25% and 100%, TAC = $B/B_{AVG} \times 0.9 \times C_{MSY}$

  If B/B_{MSY} is above 100%, TAC = $0.9 \times C_{MSY}$

How would an error band interact with TAC setting?



When female error band encompasses the threshold:

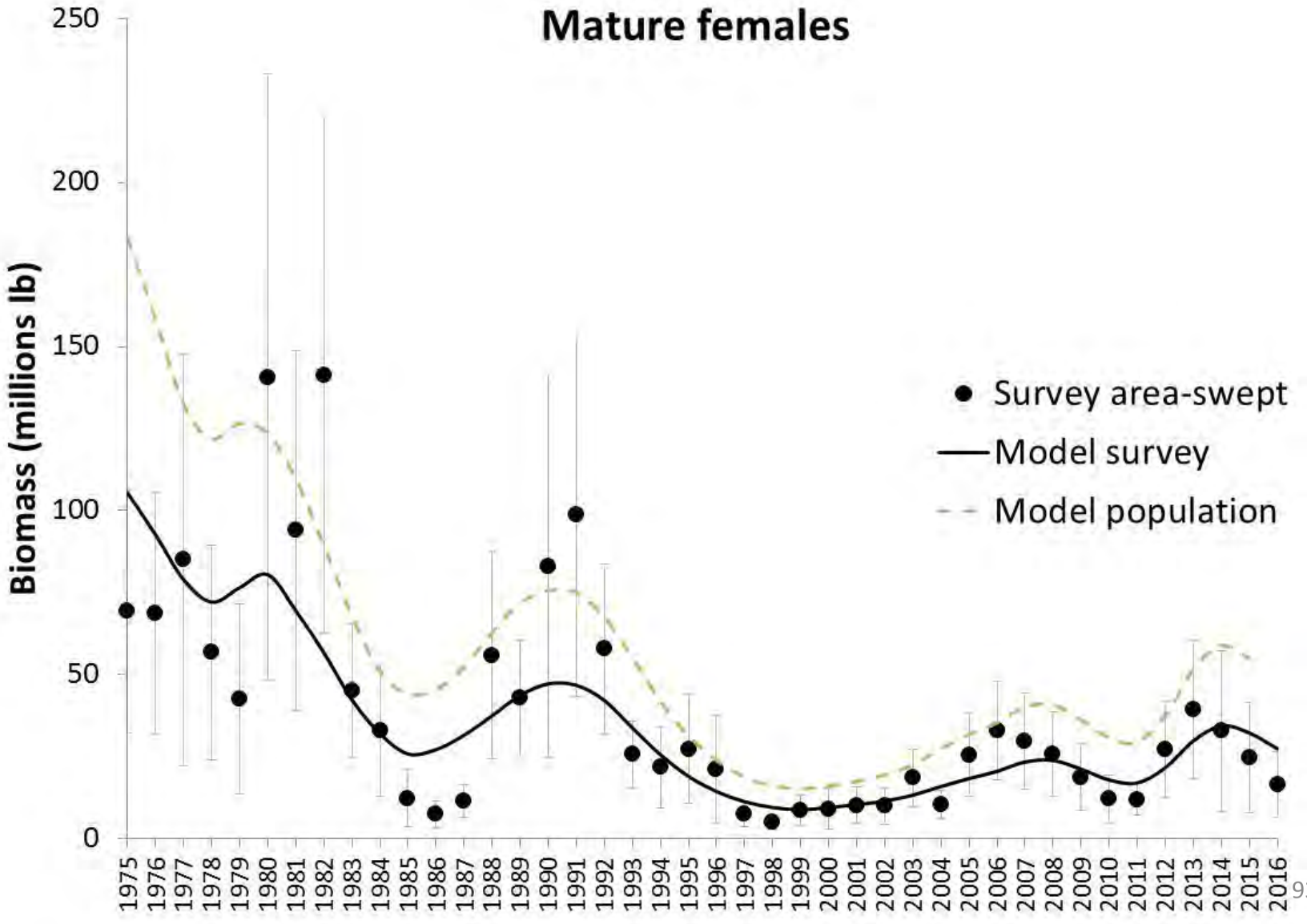
- The computed TAC is reduced by the proportion of mature males biomass above the long-term average

$(B/B_{AVG} - 1)$

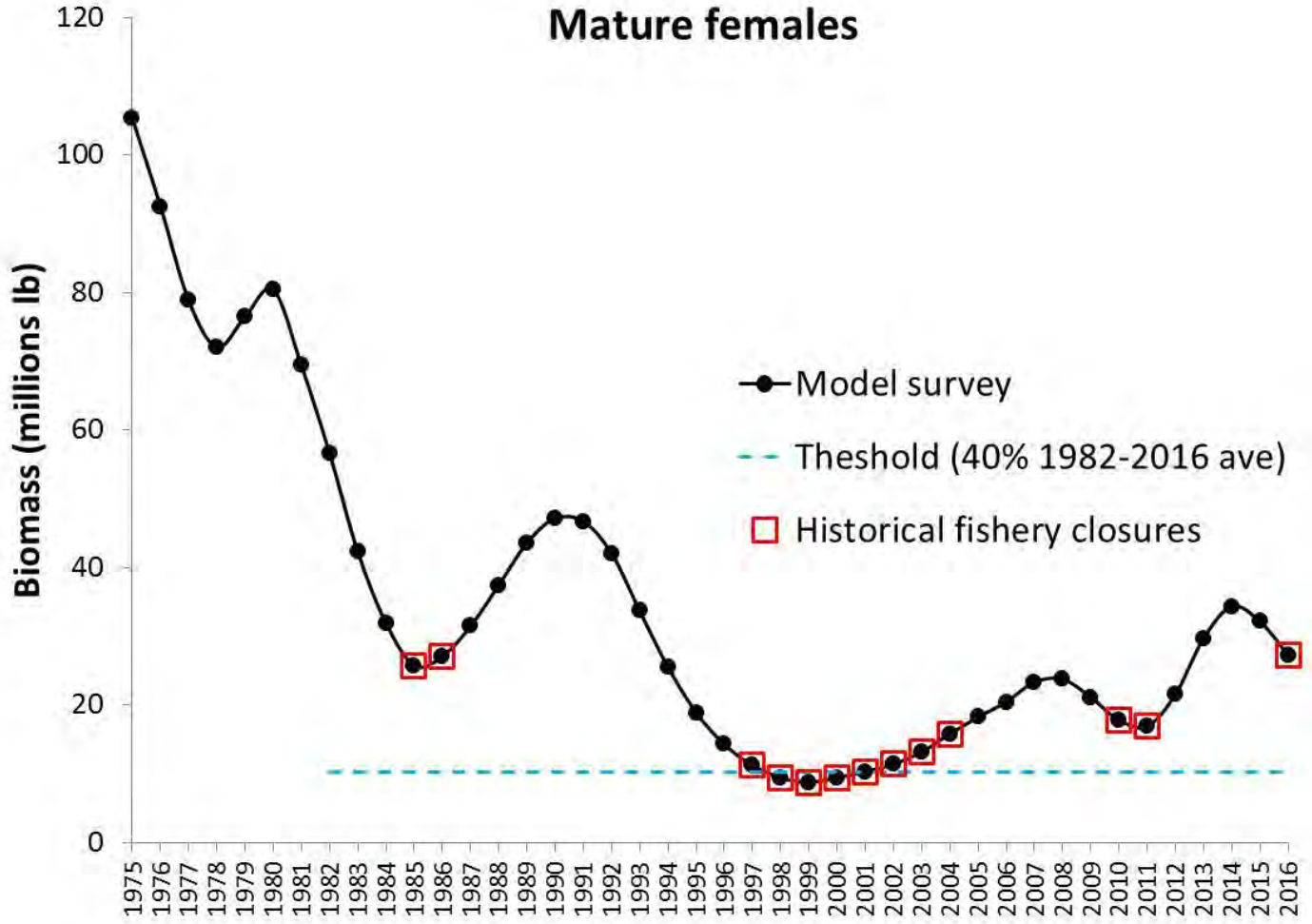
Example: 2016 estimate = 77 mill lb
Long-term ave = 42 mill lb
Proportion excess : (77/42 -1) = 0.83

2016 TAC = 0.83*computed TAC

What about model estimates?

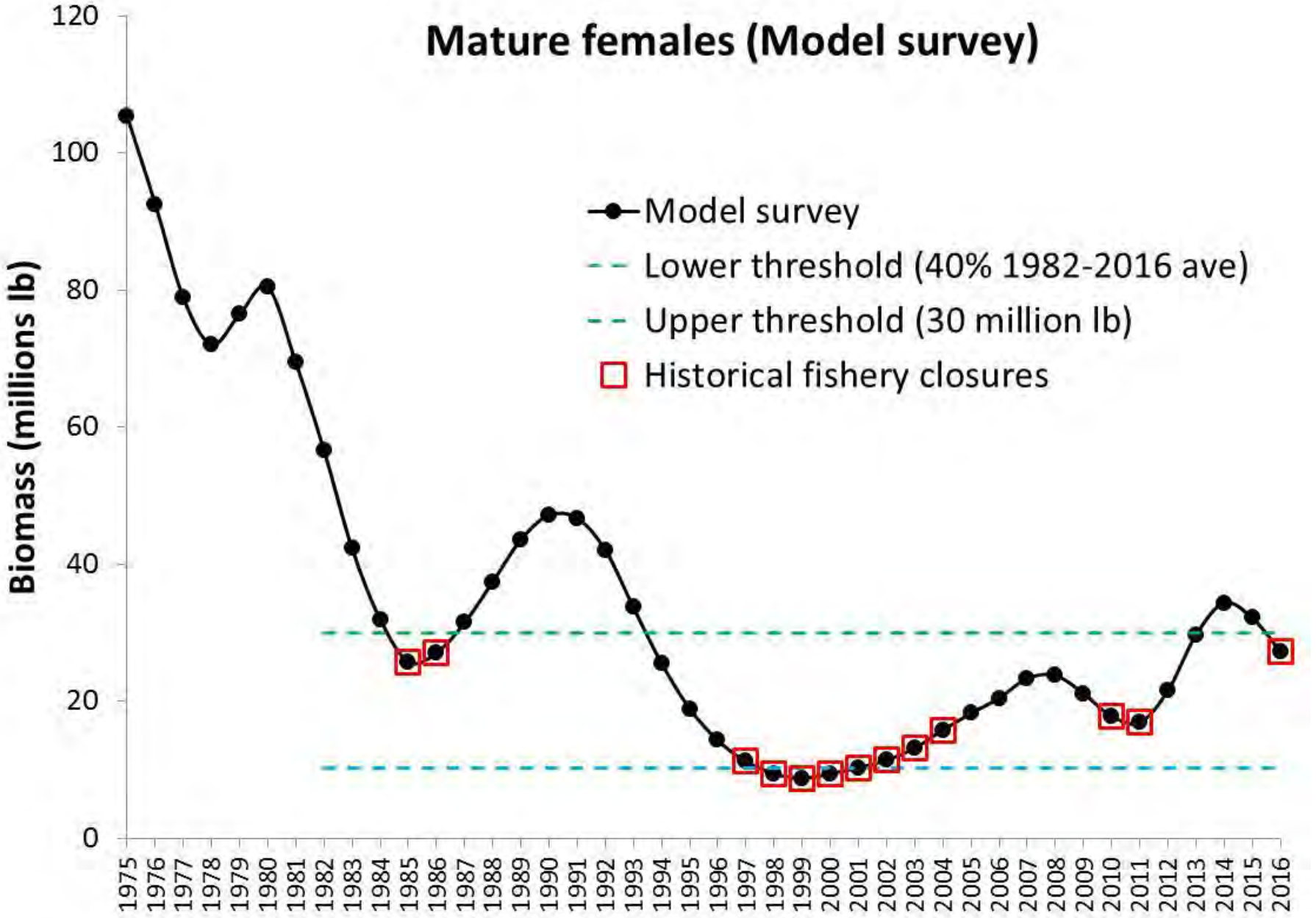


Model estimates: What criteria should be used for establishing thresholds?



What is the goal of a threshold?

- Preserve ***"minimum stock size that allows for sufficient recruitment so that the stock can rebuild itself"*** (BOF policy 5)
  - We do not know what the "minimum stock size" is.
  - We **DO know** that closing the fishery during periods of low female abundance allowed for the population reproductive capacity to recover.
  - How do we establish a threshold that captures historical closures using model estimates?


Mature females (Model survey)
Biomass (millions lb)
120
100
80
60
40
20
0
Model survey
Lower threshold (40% 1982-2016 ave)
Upper threshold (30 million lb)
Historical fishery closures
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
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2007
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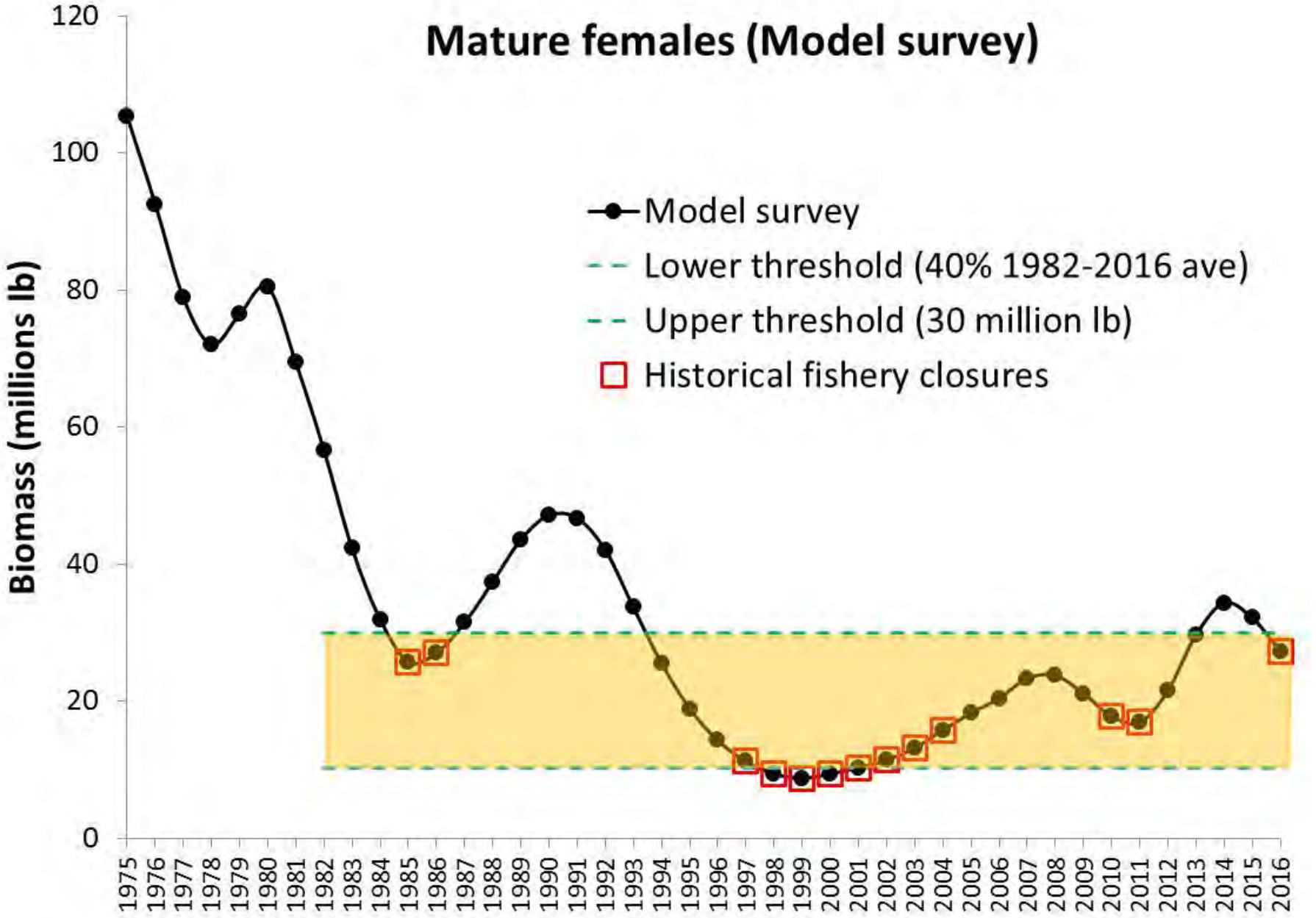
2009
2010
2011
2012
2013
2014
2015
2016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1975
1976
1977
1978
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1981
1982
1983
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1986
1987
1988
1989
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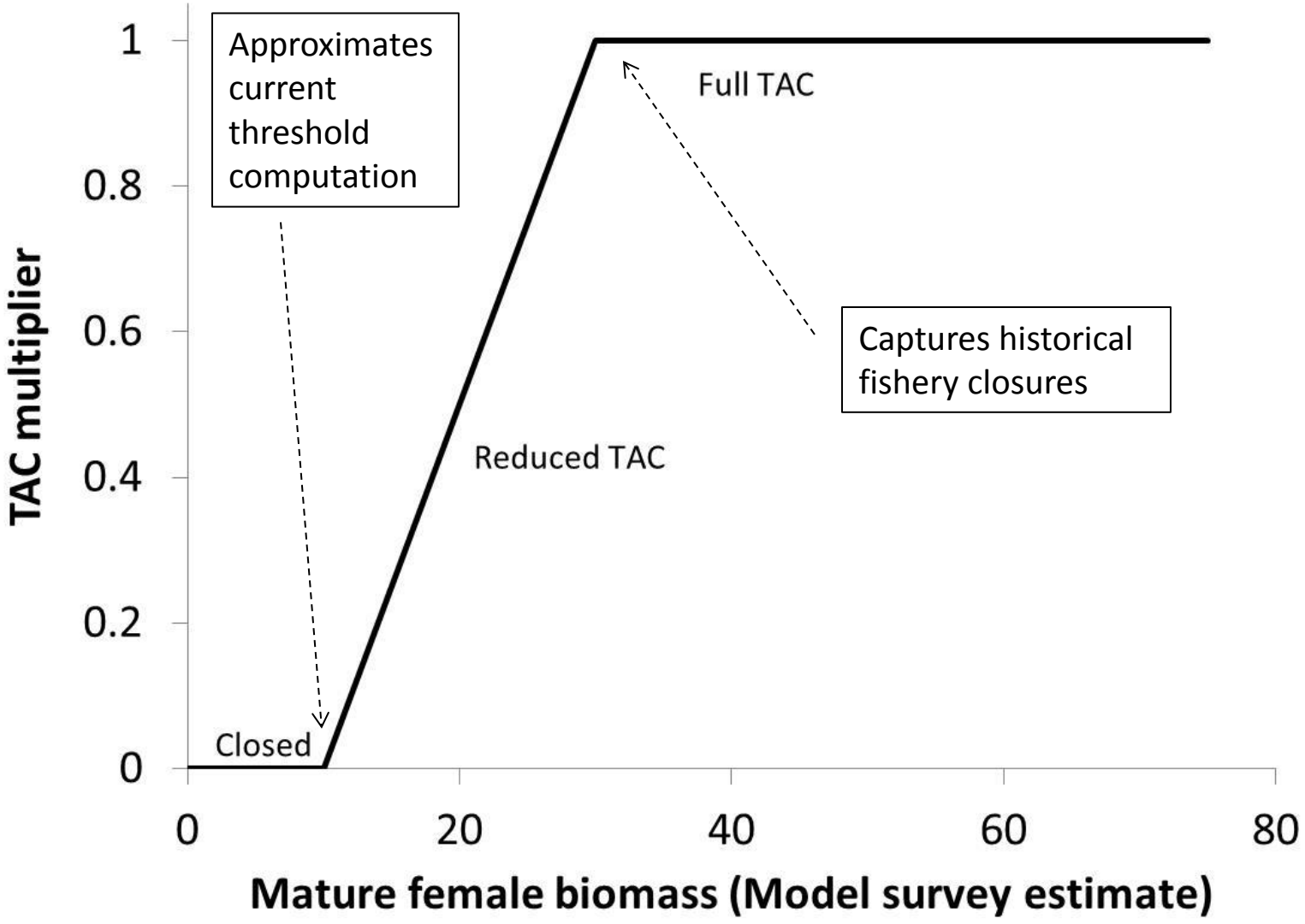
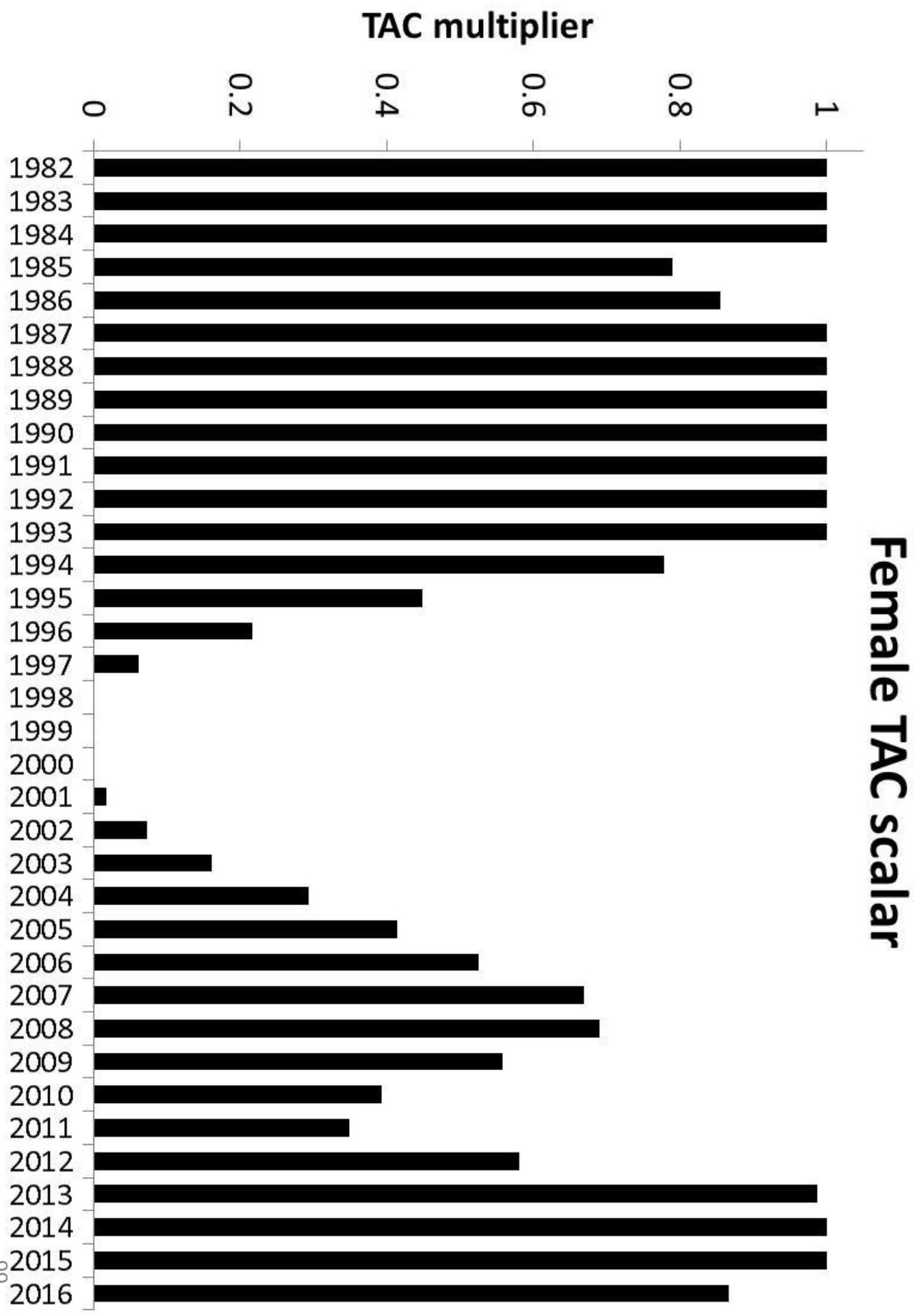
2011
2012
2013
2014
2015
2016

Sliding scale




TAC multiplier
0
0.2
0.4
0.6
0.8
1
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
Female TAC scalar

How would a female scalar interact with TAC setting?

- Computed TAC multiplied by female scalar
- Below lower female threshold results in a scalar of 0, closing the fishery
- Upper female threshold defines when the female TAC reduction multiplier would be implemented

<u>Decision points:</u>

- What are the upper and lower bounds of the sliding scale?
- Given the model estimates are being used to determine sliding scale, how do we want to define criteria for fishery closures?
  - Based on past fishery and management practices?

Possible Threshold Bounds

Lower: defines fishery closures

- 10 million lb: 40% of 1982-2016 average
- 15 million lb: captures population lows in late 1990s-early 2000s

Upper: defines point of TAC reduction

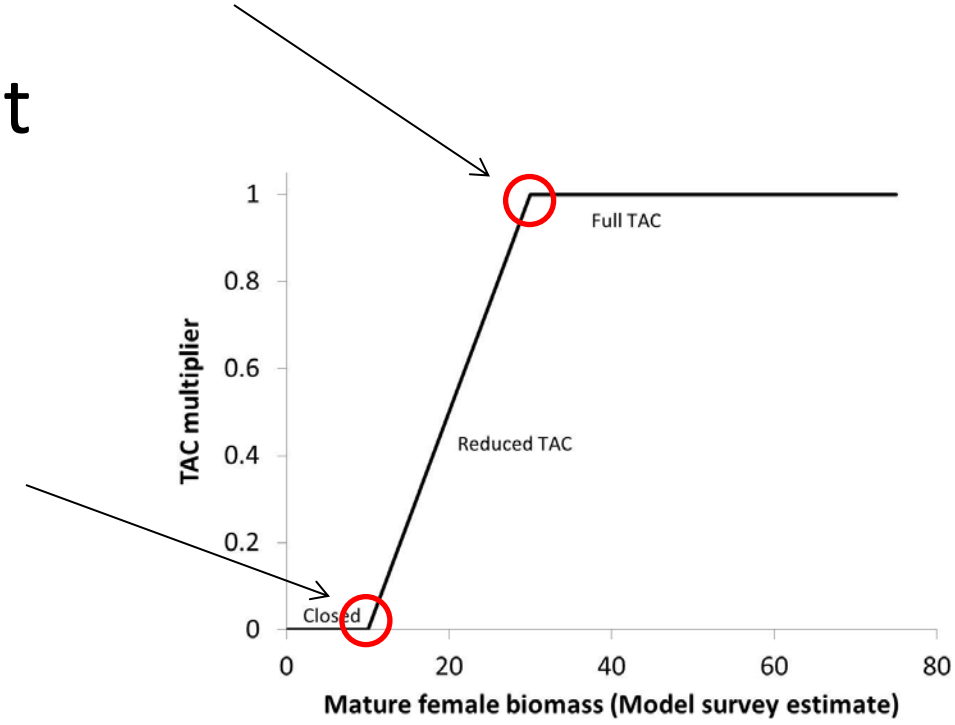
- 26 million lb: 100% of 1982-2016 average
- 30 million lb: captures all fishery closures and lows in female area-swept estimates
- 35 million lb: arbitrarily define width of 20 million lb if lower bound is 15 million lb

Effect of scalar band width and placement

Upper bound slope and placement determines how aggressively to set TACs based on females

Lower bound placement determines criteria for fishery closures

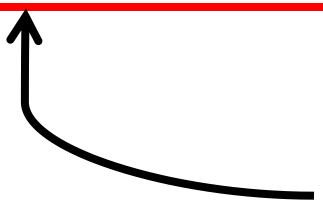
- How precautionary should we be?
- What data can inform this?



Benefits of sliding scale concept

Addresses items “E” and “F”

- By using model survey estimates, survey variance is accounted for
- Dampens the on/of switch (“light dimmer”)
- Could allow for more consistent fishery
  - Fewer closures, but TACs possibly reduced



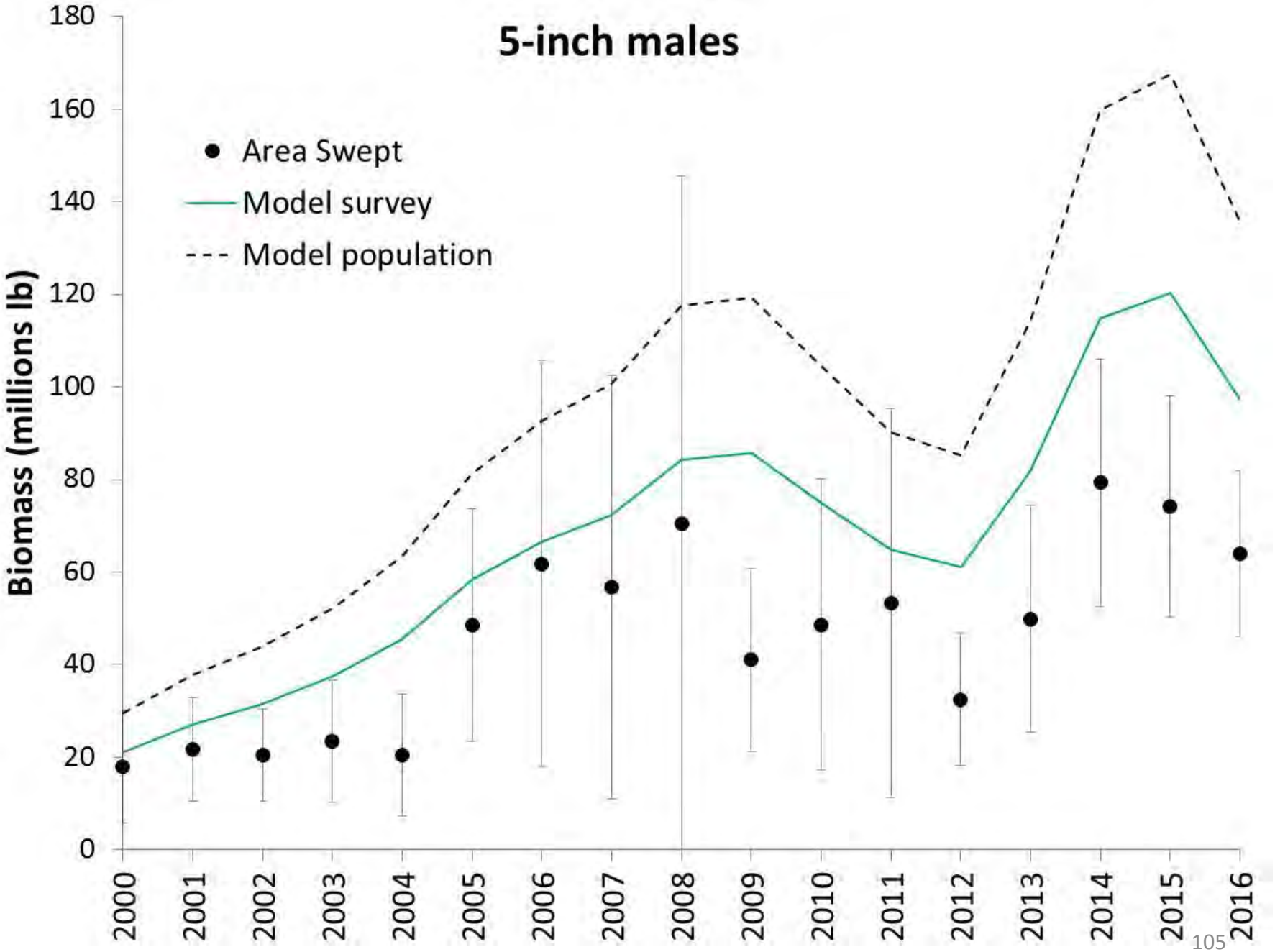
This needs more investigation

- Historical TAC comparisons are difficult because of the evolution of the harvest strategy

Challenges with using stock assessment model biomass estimates in TAC setting

- Model time-series changes each year as new data becomes available and models improve
  - Raw survey area-swept estimates are "set in stone", thus easier for the general public to understand
- Model outputs not spatially explicit, but are for entire EBS
  - challenge for setting TACs in two sub-areas
- Concerns about over estimating 5-inch males

"***The assessment model has consistently overestimated large male crab in the size compositions, which has large implications for estimation of mature male biomass and resulting OFL setting. It was suggested that the greater male growth rate estimated in the model relative to available empirical data may be contributing to this offset.***" (Crab Plan Team, Minutes September 20-23, 2016).


5-inch males
Area Swept
Model survey
Model population
Biomass (millions lb)
180
160
140
120
100
80
60
40
20
0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016

Current progress/considerations

Threshold computation:

- Years: 1982-2016
- Maturity definition: use morphology of abdominal flap
- West of 173 W long: include

50% reduction penalty clause:

- Further consideration, keep now, may remove it later

Alternatives to female open/close threshold:

- Further consideration: sliding control rule, model data
- Risk analyses for component alternatives

Considerations for this meeting

- Evaluate progress on harvest strategy updates (Elements A-D)
- Consider which elements to adopt/refine
- In place for 2017/18 season starting October 15?

Industry supportive of current work progress

Road map

- Shorter-term: fully develop sliding scale threshold alternative
  - Continued review team collaboration
- Longer-term: Investigate improvements to the harvest strategy
  - Possible interagency workshop with experts in the field to work on concepts
    - Model risk factors via management strategy evaluation
  - Think broadly about harvest strategy goals
  - Assessment model ↔ harvest strategy

Thank You!