Update: ADF&G Bering Sea Tanner crab harvest strategy revision

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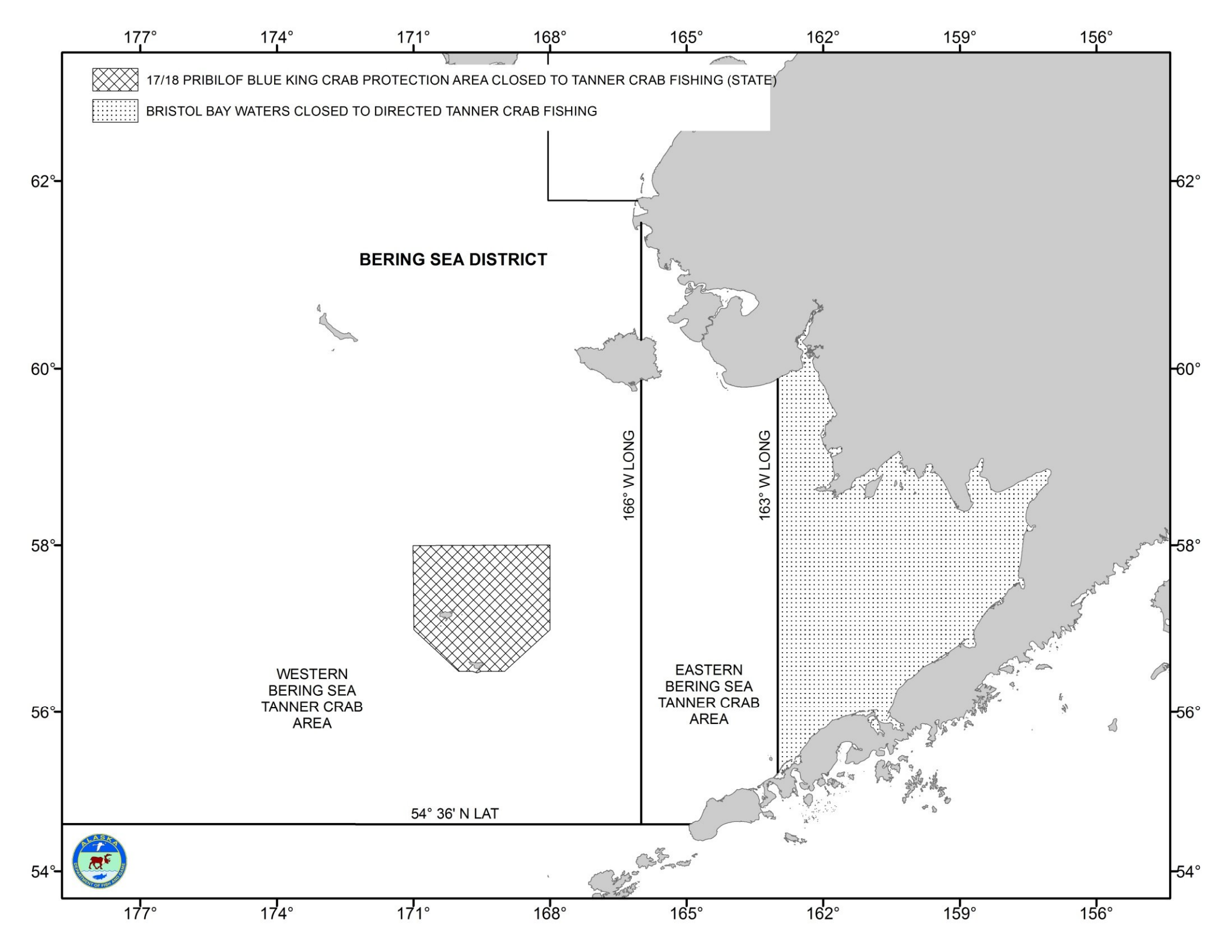
Today's presentation

- Update CPT on progress of Tanner harvest strategy revision
  - Provide context to preliminary harvest strategy scenarios
    - I will discuss past and current harvest strategies, but lets focus discussion on the future/developing harvest strategy
  - Discuss preliminary harvest strategy scenarios
  - Solicit feedback on harvest strategy scenarios and management objectives


17/18 PRIBILOF BLUE KING CRAB PROTECTION AREA CLOSED TO TANNER CRAB FISHING (STATE)
BRISTOL BAY WATERS CLOSED TO DIRECTED TANNER CRAB FISHING
BERING SEA DISTRICT
166° W LONG
163° W LONG
WESTERN BERING SEA TANNER CRAB AREA
EASTERN BERING SEA TANNER CRAB AREA
54° 36' N LAT
177°
174°
171°
168°
165°
162°
159°
156°
62°
60°
58°
56°
54°

3-S: Size/Sex/Season

- Legal size, males only, no fishing during molting and mating season (~spring, early summer)

- Legal size
  - 1976: legal size was implemented
    - Before 1976, processors regulated sizes based on market considerations.
  - Before 2010: based on Kodiak Tanner crab growth and reproductive data: 5.5”(140mm) for all areas except 5.3” for PWS Tanner crab, which has smaller size at maturity.
  - After 2010, exploitable legal males changed due to considerations of temporal and spatial variation in size at maturity.
    - east of 166° W: preferred 5.5” [legal 4.8”]
    - west of 166° W: preferred 5.0” [legal 4.4”]
  - In 2015, exploitable legal size for eastern Bering sea Tanner crab, east of 166° W was reduced from 5.5” to 5.0” to align the harvest strategy with the industry-preferred minimum size.

- 3-S based on economic considerations of market value and meat yield, fishing opportunity, protection of females for reproduction, and the intent to allow at least one mating season for mature males prior to harvest.

EBS Exploitation/Harvest Rates in 1974

- Exploitation rate of 40% on legal male abundance for eastern Bering Sea Tanner crab in 1974 was considered low at that time “with the intent of dampening inter-year variation in catch by spreading the harvest of each year-class over more years (this philosophy is known as multiple year-class management)” (Somerton 1981, PhD dissertation).

- With stock collapse in mid and late 1990s, the 40% exploitation rate has been considered to be too high.

EBS Harvest Strategy Updated in 1999

- Mature female (>79 mm CW) threshold: 21 million lbs in Eastern Subdistrict (east of 173° W long.)
- Exploitable Mature Male (100% newshell+15%oldshell) harvest rates:
  - 0 when mature female biomass is <21 million lbs
  - 0.1 when mature female biomass is ≥21 and <45 million lbs
  - 0.2 when mature female biomass is ≥45 million lbs
- Legal harvest cap: 50% of exploitable legal males
- Separate east-west management at 168°W (changed to 166° W later to align with the Bristol Bay red king crab fishery)
- ½ reduction rule: reduce TACs to ½ of computed value if previous years failed to meet threshold

EBS Harvest Strategy Updated in 1999

- Computer simulation study
  - Aimed at trade-off between in high catch and low catch variation
  - Low probabilities of overfishing and fishery closures

- Female threshold
  - Weak S-R relationship: threshold set based on past fishery management practice and partly on the S-R relationship.
  - Bristol Bay Tanner crab (east of 168°W) before 1999, 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 was expanded to the EBS by dividing by 0.75 (= 21 million lbs) because during 1976-1998, ~75% of mature male and female biomass and 82% of legal males occurred in Bristol Bay.

- Generally adjusted legal harvest rates according to changes in stock productivity indexed by recruitment strength:
  - High legal harvest rates during upward recruitment periods
  - Low rates to protect large-size crab and reproductive potential during downward recruitment periods (Zheng and Kruse 1999).

Mature Female Threshold: 1999

- Following Bristol Bay RKC, effective spawning biomass (ESB) was developed for Bristol Bay Tanner crab (Zheng and Kruse 1998), as a function of:
  - mature female and male abundances and biomasses,
  - shell conditions; newshell and oldshell mature female densities,
  - previous matings and mating proportions of newshell males,
  - Assumption: At low densities, 1 mate-able male can mate with 1 primiparous (newshell) and 1 multiparous (oldshell) female.
  - Assumption: At high densities, 1 mate-able male can mate with 5 primiparous and 3 multiparous females

Paul 1984

- Mature female biomass was recommended to substitute ESB for the harvest strategy (Zheng and Kruse 1998, 1999)
  - No model for Pribilof Island Tanner crab + the complexity to compute ESB for Bristol Bay Tanner crab
  - For a majority of years, ESB = mature female biomass

EBS Harvest Strategy Updated in 2011

- Mature Female threshold: 40% of 1975-2010 average biomass in Eastern Subdistrict (about 21 million lbs before NMFS changed area-swept estimates of survey abundance)
- Male harvest rates:
  - 0 when mature male (MM) biomass is less than 25% of 1975-2010 average
  - $(0.9) \times (B/B_{AVE}) \times C_{MSY}$ when MM biomass is between 25-100% of 1975-2010 average
  - $(0.9) \times C_{MSY}$ when MM 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
- B and B_{ave}: at preseason survey time
- C_{MSY} : catch biomass at mating time (Feb 15)

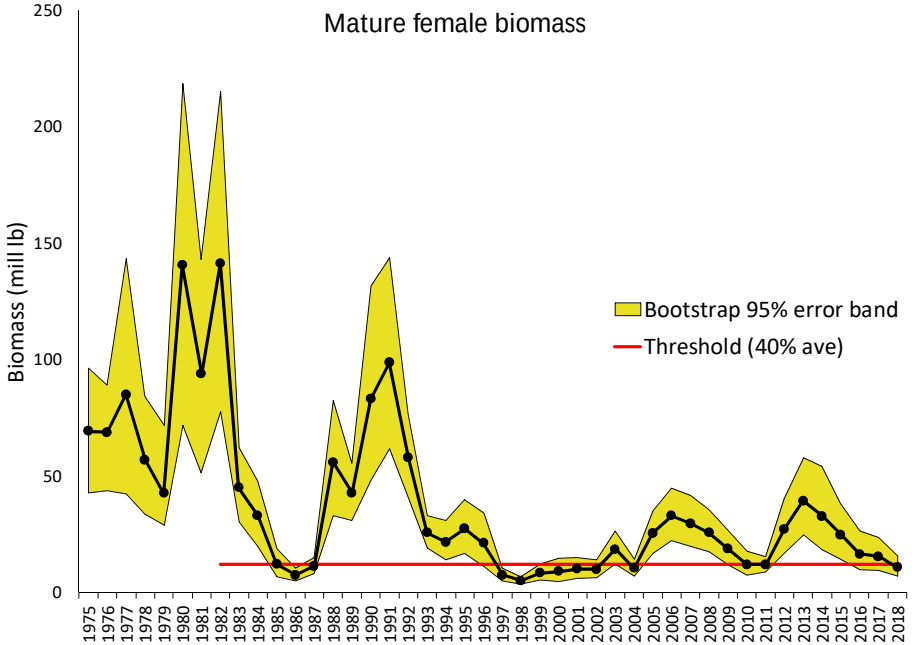
Why Update Harvest Strategy in 2011?

- Mature male terminal molt
  - Accepted during mid and late 2000s (Tamone et al. 2007)
  - Affects legal sizes and optimal harvest rates
- Spatial and temporal changes in size at maturity (Zheng 2008)
  - Different “exploitable” (preferred) and legal sizes in two areas
- Attempt to better align state harvest strategy with Federal ABC approach
  - Uses model estimated F_{OFL} (F_{MSY}) and fishery selectivity to estimate MSY (C_{MSY})
  - OFL-approach: male biomass threshold, harvest rate adjustments, and a 0.9 buffer
- Overall:
  - Address terminal molt, temporal & spatial changes in size at maturity
  - Increase mean yield, reduce on-deck sorting time & discards, avoid excessively targeting of fast-growing large males

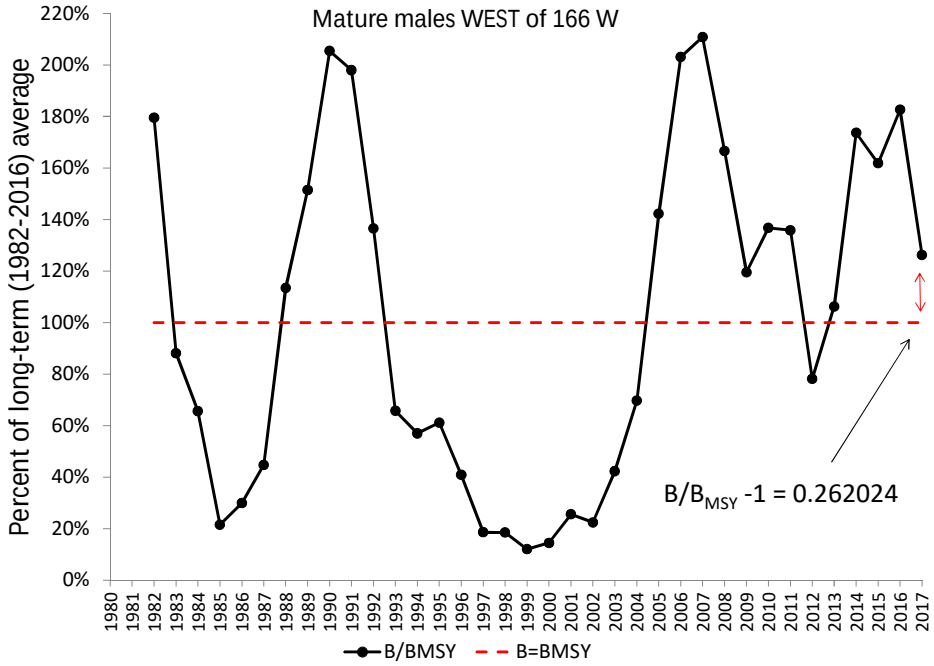
EBS Harvest Strategy Updated in 2017

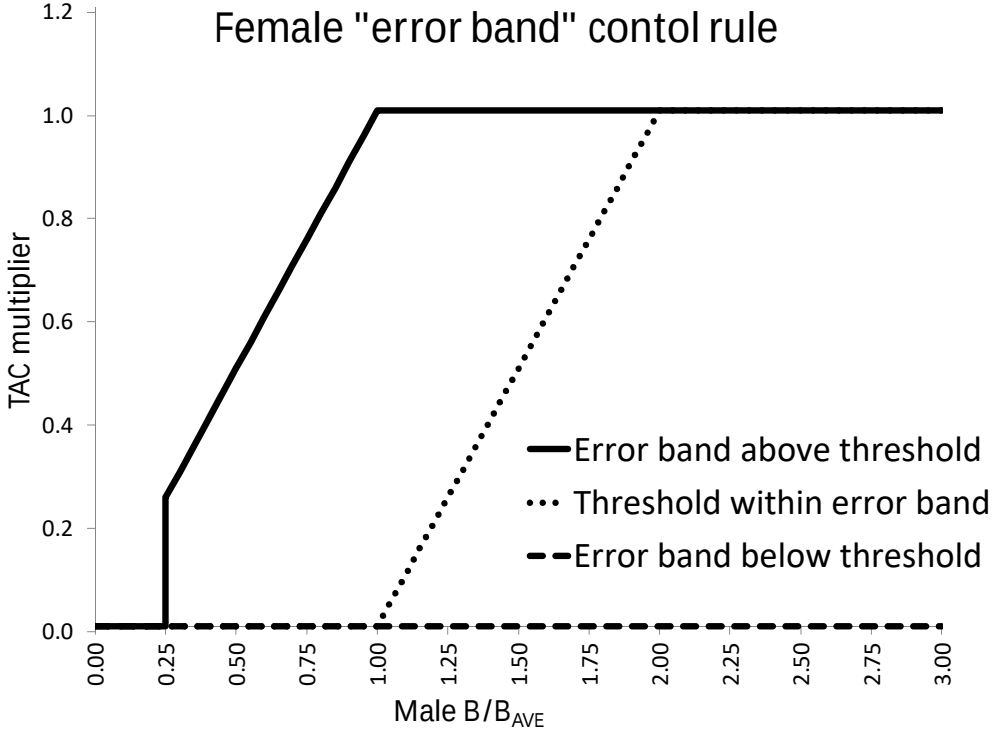
- Mature Female threshold: 40% of 1982-2016 average biomass in total NOAA survey area, maturity determined by abdominal flap
- Female error band rule:
  - Reduced male exploitation when female threshold falls with 95% CI (incorporate survey variance)
- Male harvest rates (threshold below lower bound of CI):
  - 0 when mature male (MM) biomass is less than 25% of 1975-2010 average
  - (0.9) x (B/B_{AVE}) x C_{MSY} when MM biomass is between 25-100% of 1975-2010 average
  - (0.9) x C_{MSY} when MM 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 threshold above upper CI bound
- B and B_{ave}: at preseason survey time
- C_{MSY} : catch biomass at mating time (Feb 15)

EBS Harvest Strategy Updated in 2017



Threshold within error band





Why the female error band rule?

- Buffer “on/off” switch based solely on female biomass
- Incorporate uncertainty
- Allow fishery when females are low, but male biomass suggests a harvestable surplus is available
- Ensure males are available for mating when female recruitment improves
  - SC3 “oldshell” males may have 4-5 more years of reproduction*

*Based on snow/Tanner research: gonad size, sperm allocation, senescence effects, new/oldshell inter-molt duration, life expectancy, etc.

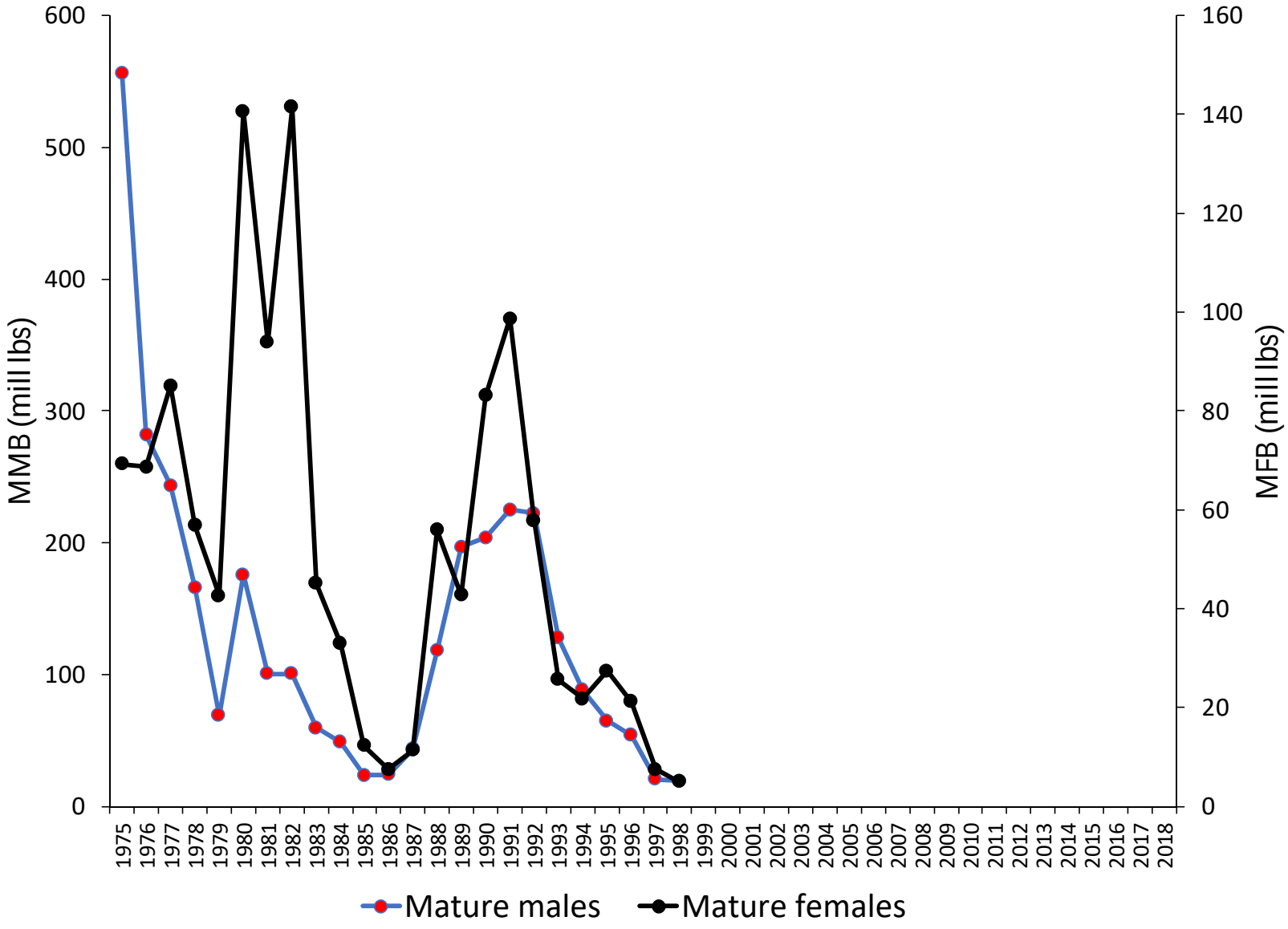
Harvest strategy updates

	1999	2011	2017
Female threshold	21 mill lb (females ≥ 79 mm CW, east of 173°W)	40% of 1975-2010 average (females ≥ 80 or 85 mm CW, east of 173°W)	40% of 1982-2016 average ("actual" maturity, entire EBS surveyed area)
East/West line	168°W	166°W	166°W
Male threshold	25% B_{AVE}	25% B_{AVE}	25% B_{AVE} if error band above threhold; 100% B_{AVE} if threshold within error band
Male exploitation	Mature males (100% newshell + 15% oldshell): Stairstep: 0% when females <21 mill lb, 10% when females ≥21 and <45 mill lb, 20% when females ≥45 mill lb	(F_{MSY} x exploited males) x (B/B_{AVE} x 0.9)	(F_{MSY} x exploited males) x (B/B_{AVE} x 0.9) if error band above threshold; (F_{MSY} x exploited males) x (B/B_{AVE} - 1) if threshold within error band
Definition of "exploited legal males"	100% newshell + 32% oldshell legal males	East: 5.5 inch males x fishery selectivity; West: 5.0 inch males x fishery selectivity	East: 5.0 inch males x fishery selectivity; West: 5.0 inch males x fishery selectivity
Legal harvest cap	50% of exploited legal males	50% of exploited legal males	50% of exploited legal males
Female 1/2 TAC penalty	Reduce TACs to ½ of computed value if previous year failed to meet thresholds	Reduce TACs to ½ of computed value if previous year failed to meet thresholds	Reduce TACs to ½ of computed value if previous year error band was below threshold

Why Females?

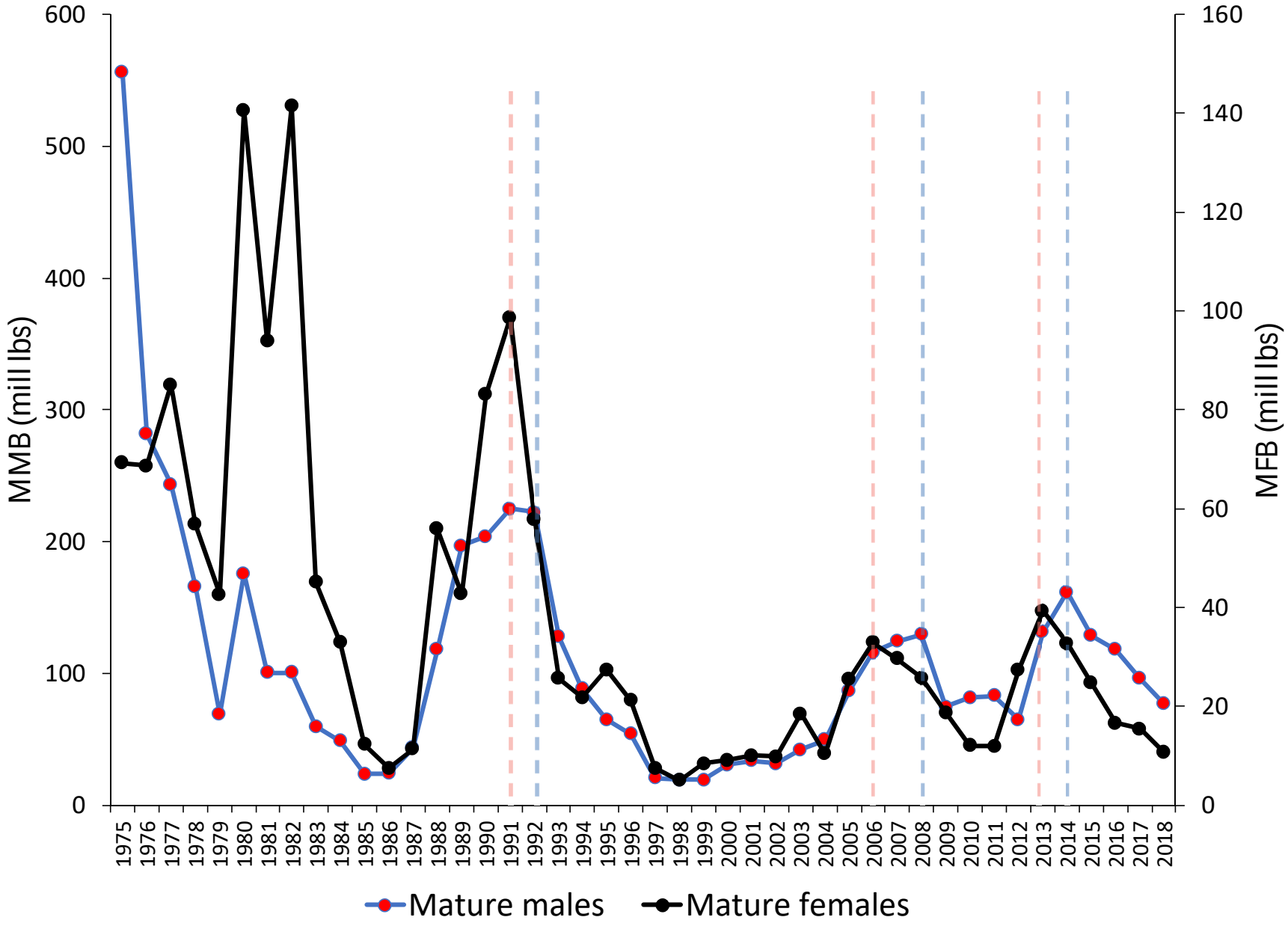
- Low female abundance = low egg produc?on → low capacity to produce future recruitment
- Predictor of male population abundance (*see next 2 slides)
- Fishery closures meant to preserve females and males
  - Females: egg production
  - Males: available for future recruitment of females
- Causes for 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."*

- Dramatic fluctuations
- Following precipitous decline, 1998 was lowest in time-series for both males and females
- 1999-declared overfished, NPFMC-BOF joint Rebuilding Plan



Highly variable/episodic recruitment:

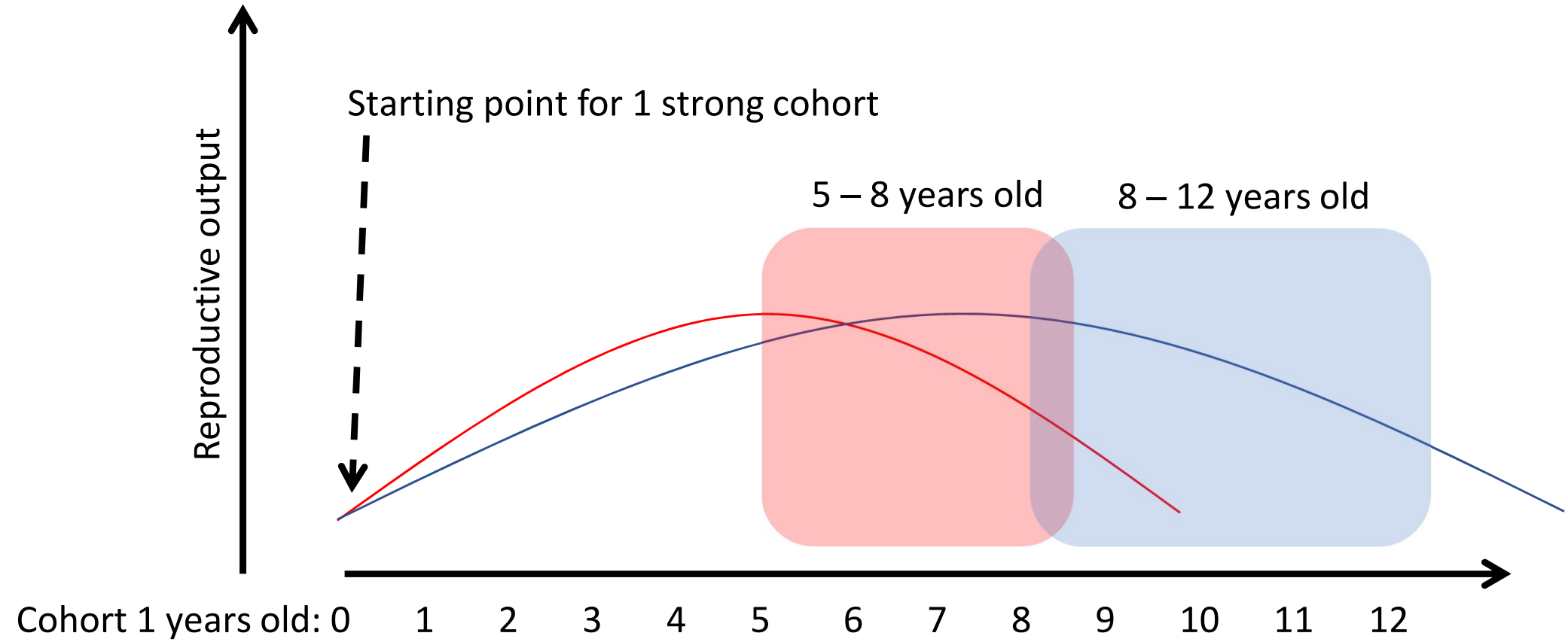
- Male increases/decreases tend to lag those of females by 1-2 years
    - Female Tanner crab mature at younger age/smaller size than males



NOAA area-swept

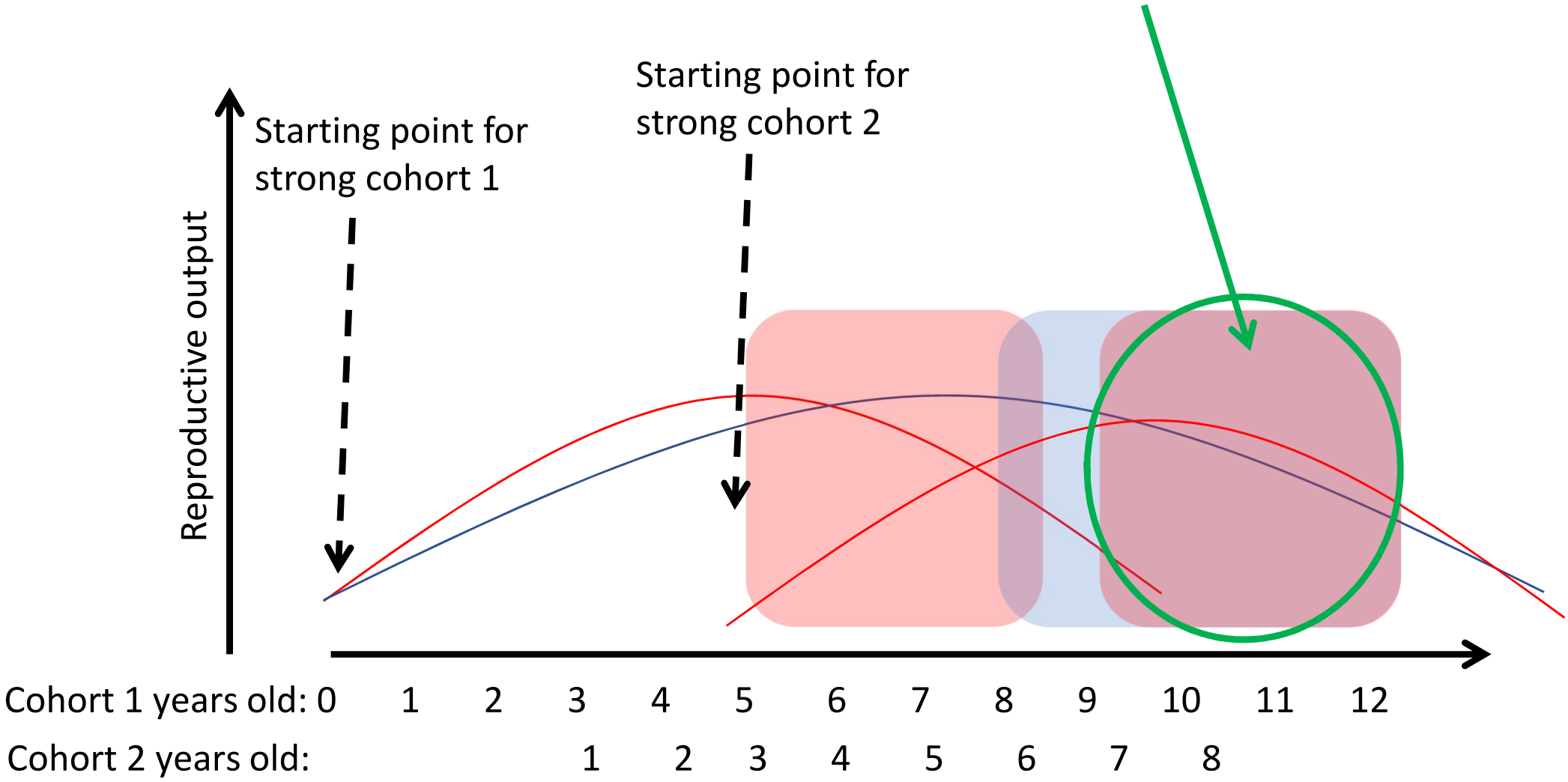
Mating Overlap

Reproductively important years are offset for females and males from the same cohort



Mating Overlap

Hope that reproductively important years for females from the next cohort overlap with reproductively important years for males from last cohort



December 2017 Workshop

- Collaborative 2-day meeting among agency, industry, academia
- Discussed importance of females, among other topics
- Consensus on females?
  - No “yes/no” consensus
  - Could be an important consideration……

Ben's thoughts

Simplify harvest strategy

- Select population estimates based on "best science"
- Apply exploita?on rate to MMB or LMB → TAC
- Eliminate thresholds that cause sharp drops in TAC

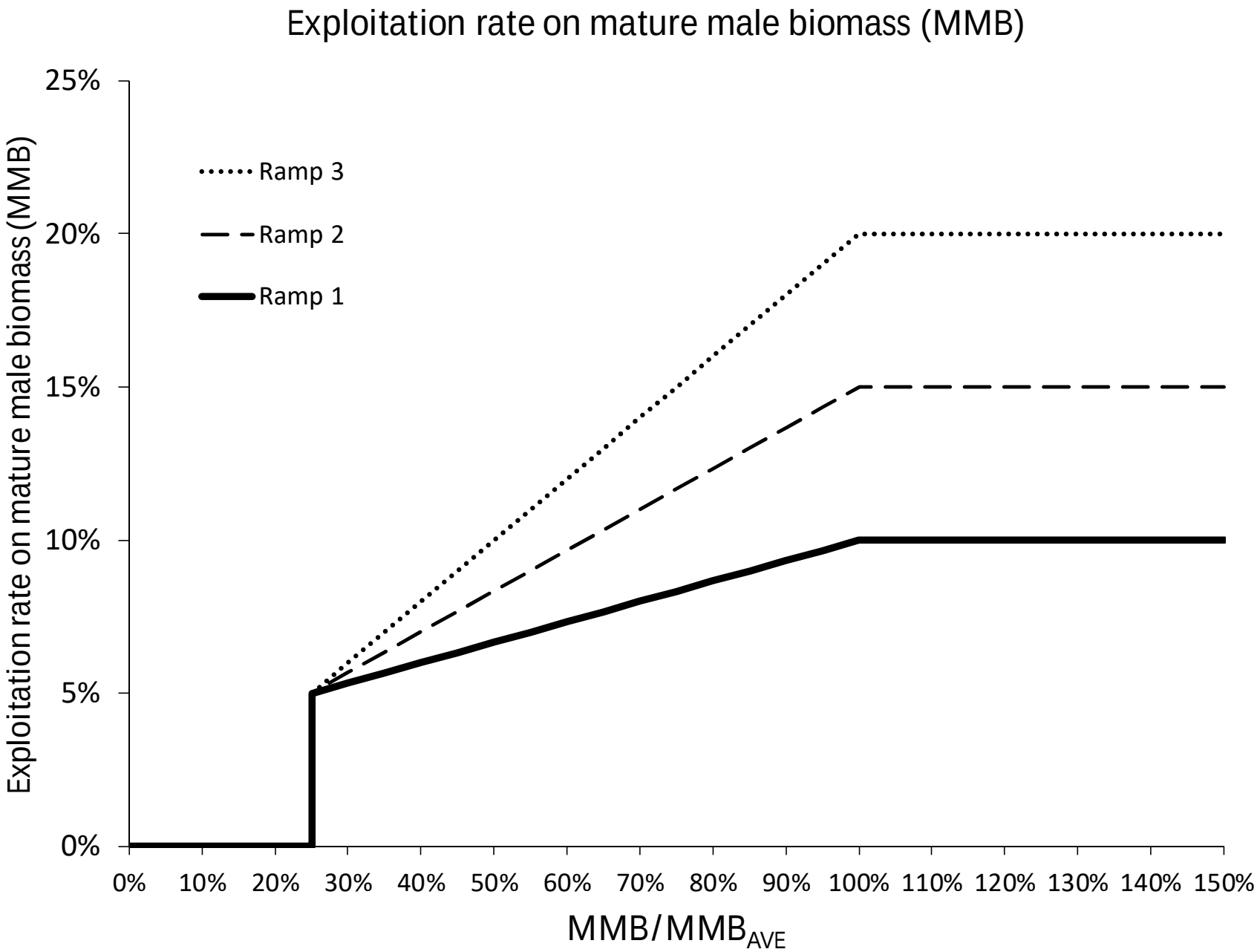
More flexible approach that allows selection of best* population estimates (i.e., area-swept vs model)

- *Goal is to use model estimates, but have been uncomfortable with model estimates of industry preferred males (i.e., ≥ 127 mm CW)

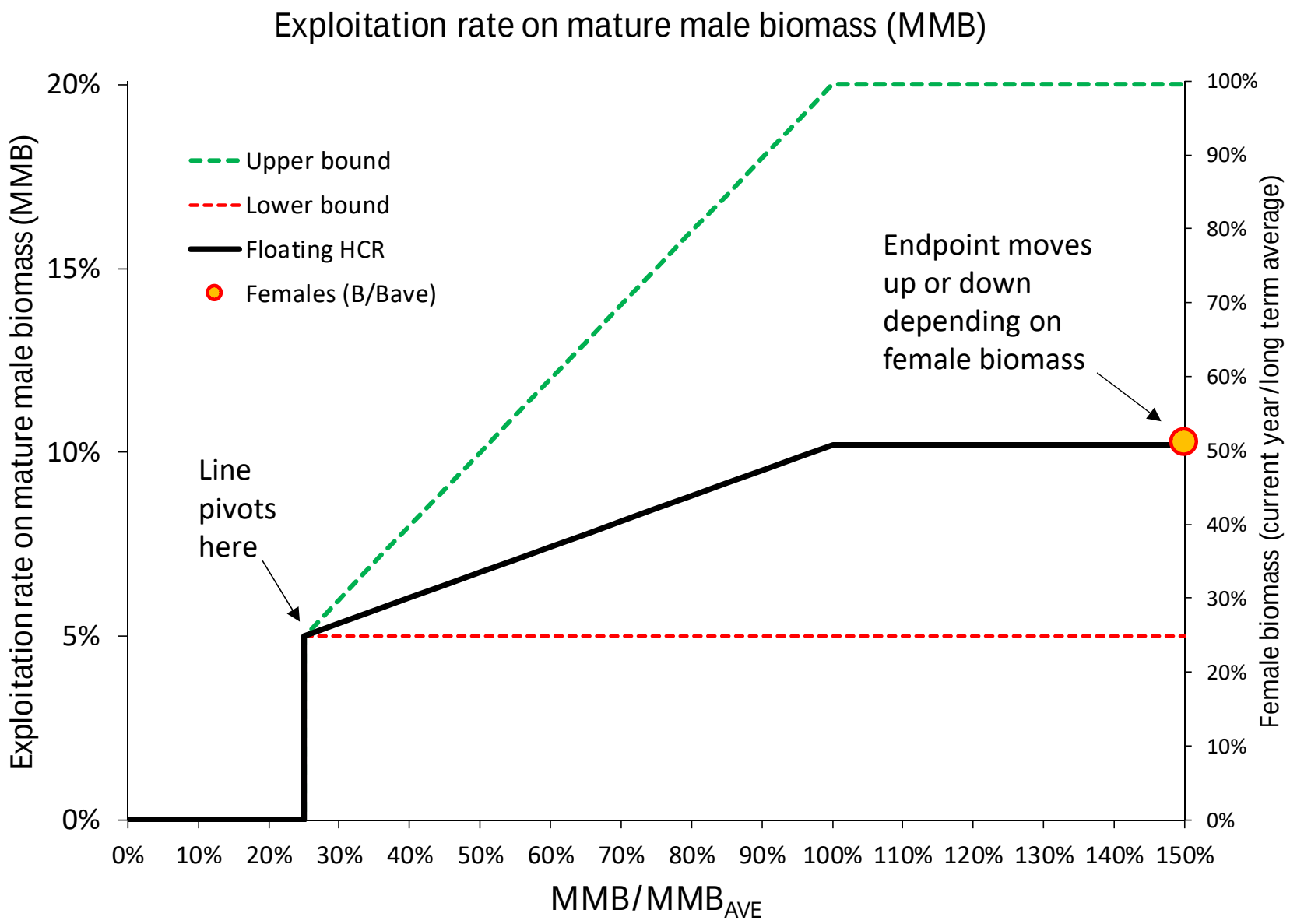
What about females?

- Uncertainty about female harvest control rule in a male only fishery
- Reduce removal of males when females are low to "bank" males for incoming female recruits…….is this needed to protect reproductive potential?
- Consider via MSE: range of scenarios
  - No female considera?on → Full female considera?on

Scenario 1: Male only “ramp”



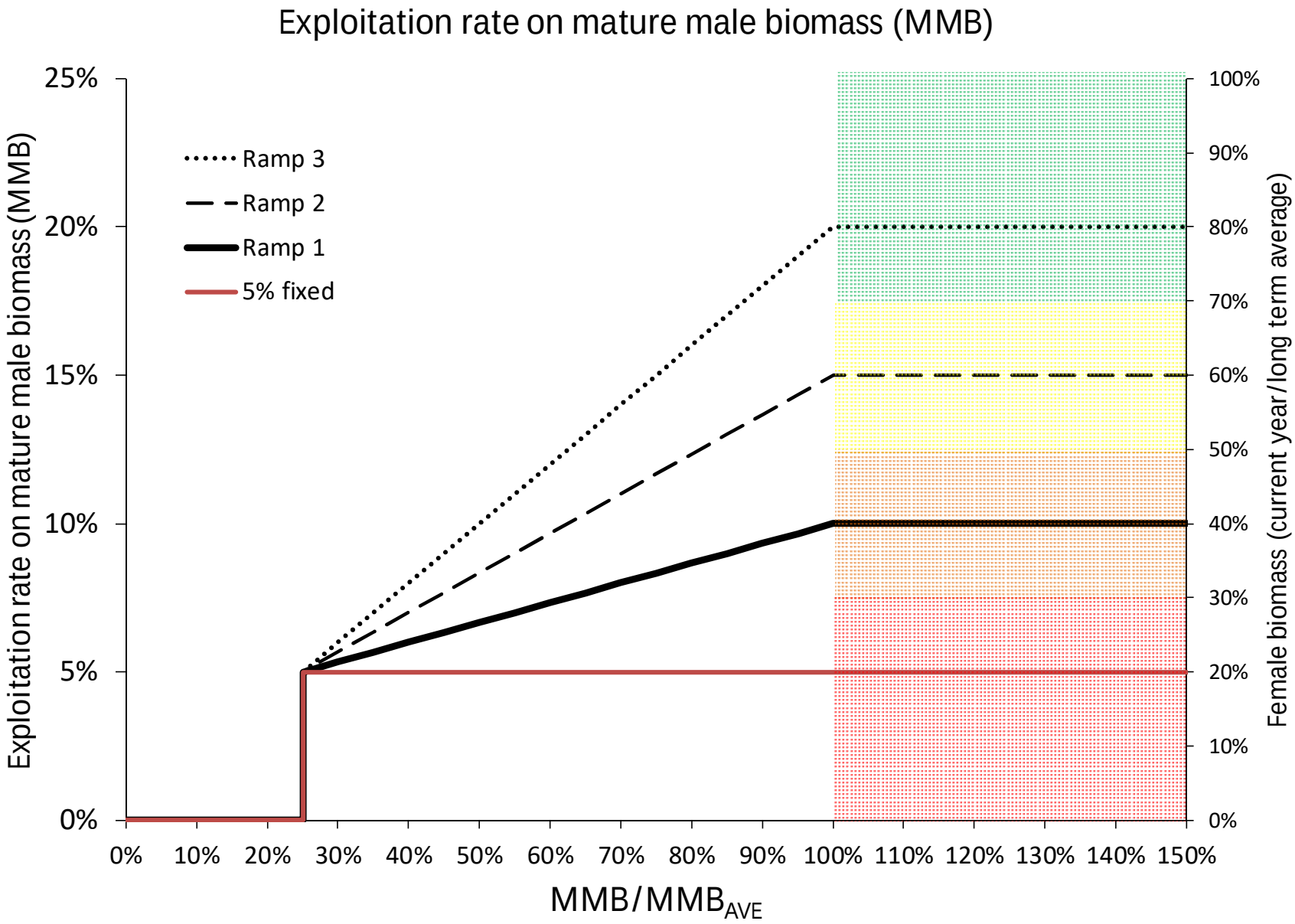
Scenario 2: Female “floating dimmer”



Scenario 2: Female “floating dimmer”

- Exploitation rate on males has an upper and lower bound
- HCR “floats” within those bounds depending on female biomass
- Zero closures based solely on females: exploitation rate bottoms out at %5 regardless of how low female abundance is
- Goal: reduce male exploitation rate when female abundance is low to ensure available males for future incoming females

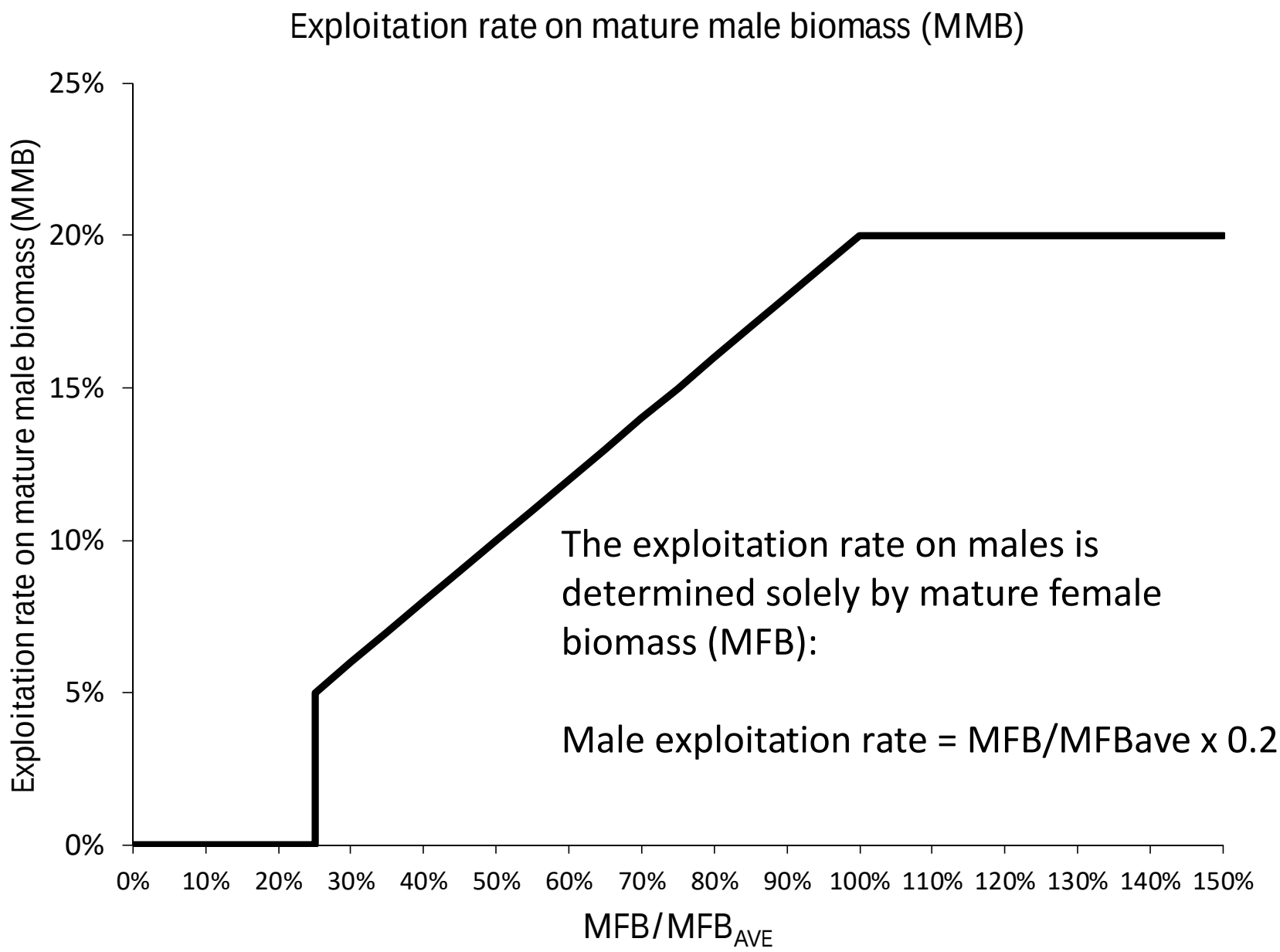
Scenario 3: Female “blocked dimmer”



Scenario 3: Female “blocked dimmer”

- Coarser version of scenario 2: The HCR line is determined by the range of MFB/MFBave.
  - For example, if MFB/MFBave=52%, then the HCR is “Ramp 2”
- Zero closures based solely on females
- Goal: reduce male exploitation rate when female abundance is low to ensure available males for future incoming females

Scenario 4: Female “ramp”



Scenario 5: ABC rule

TAC = ABC

Legal harvest cap (applies to scenarios 1-5)

- Common in other BSAI crab harvest strategies
- Could harvest 100% of legal or exploitable males under certain population structures……cap prevents this

Cap TAC at 50% of exploitable legal males (ELM)

- 5 inch males: 100% newshell + 25% oldshell

- Calculation=

$$ELM = (\%_{surv\_newshell} \times Abund) + (Os_{expect\_selectivity} \times \%_{surv\_oldshell} \times Abund)$$

$$MAX\ TAC = 0.5 \times ELM \times wt_{5\text{-inch male}}$$

Scenario 6: ELM rule

TAC = 30%, 40%, or 50% of ELM

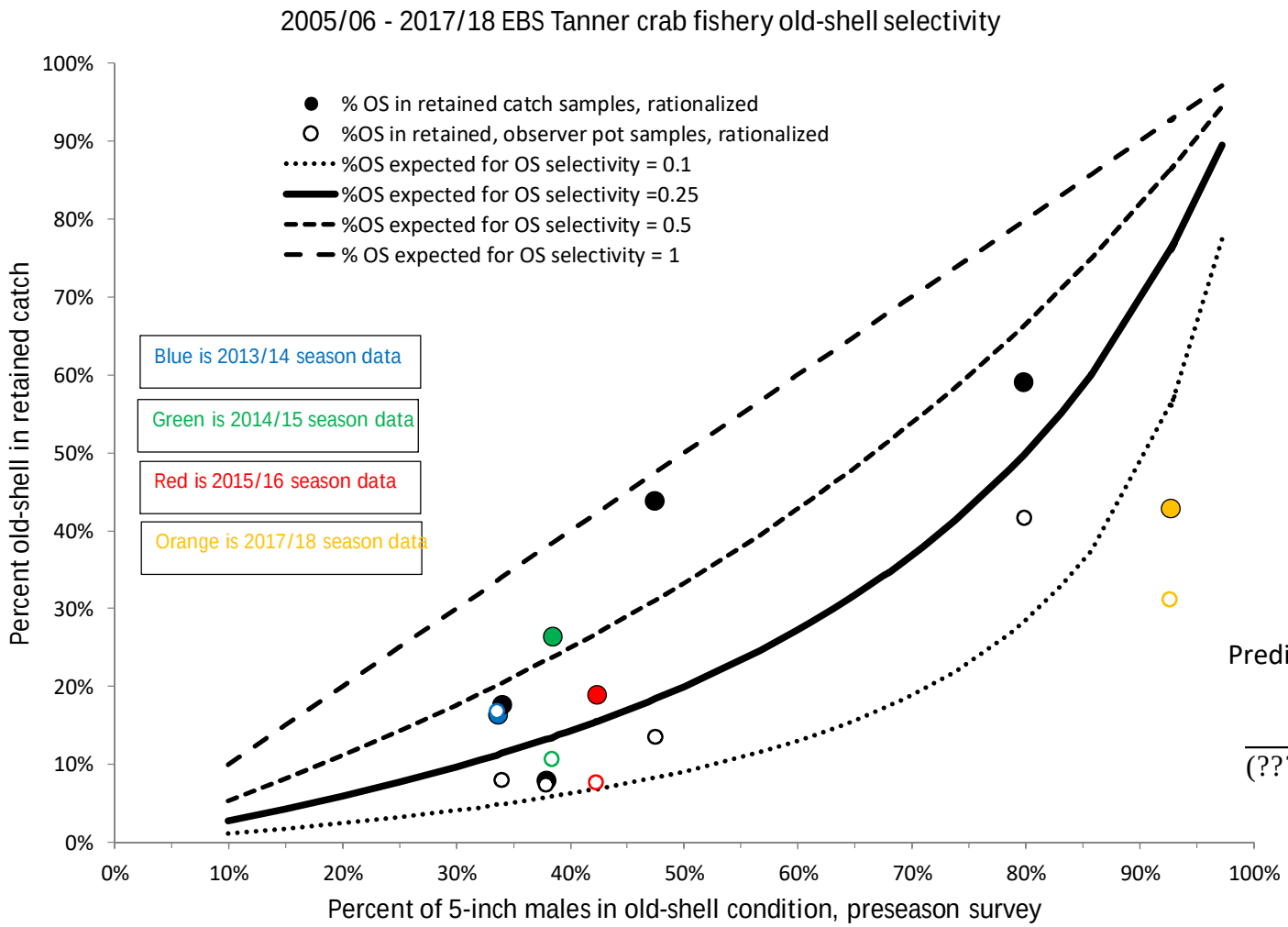
ELM= “exploitable legal males”

- Consider selectivity of oldshell crabs: industry generally prefers “clean” crab (i.e., mostly newshell landed)
- 5 inch males: 100% newshell + 25% oldshell

Scenario 6: ELM rule

Expected oldshell selectivity rate?

- 25% seems reasonable based on past fisheries



Predicted %OS in retained catch (lines)=

$$\frac{??\,??\,???\,??\,?\;\%?\;?_{??\,???}}{(??\,??\,???\,??\,?\;\%?\;?_{??\,???}\;+\;\%?\;?_{??\,???})}$$

Management Objectives?

- Maintain MMB at or above 50% long-term average
- Trade-off between high catch and low catch variation
  - Mean harvest of X mill lbs (value TBD)
  - Harvest CV of 15 (or other value)
- Probability of fishery closures <0.20 (or other value TBD)

……need feedback