Chionoecetes Crabs Female Reproductive Potential and Connection to Sex-Selective Harvest

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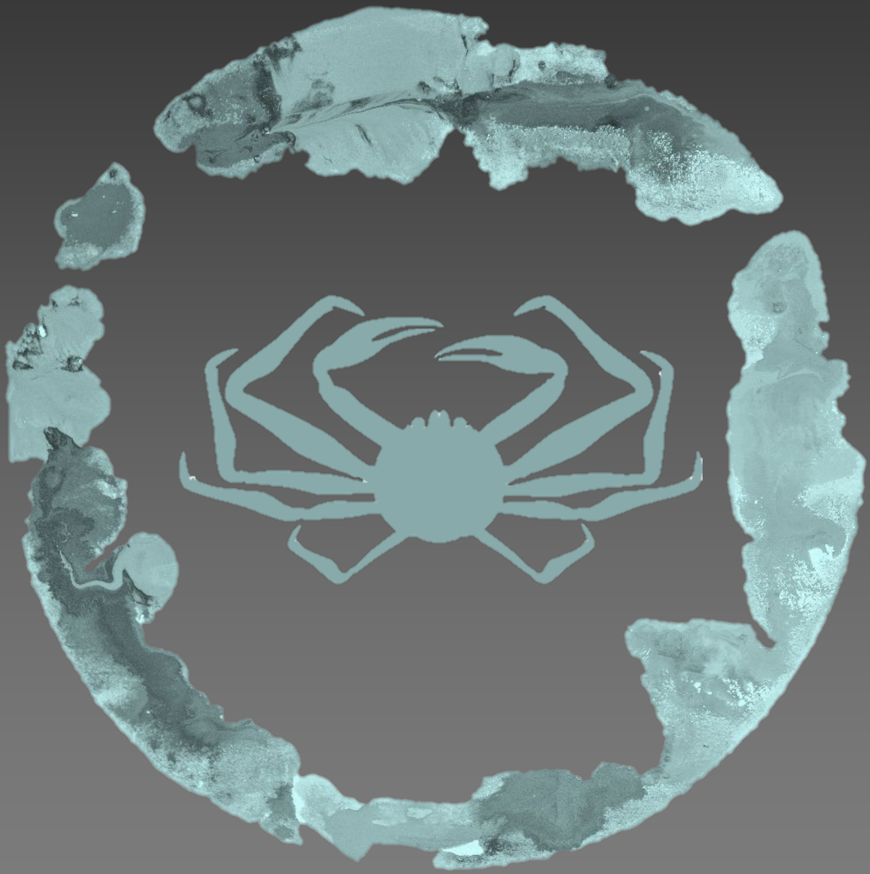
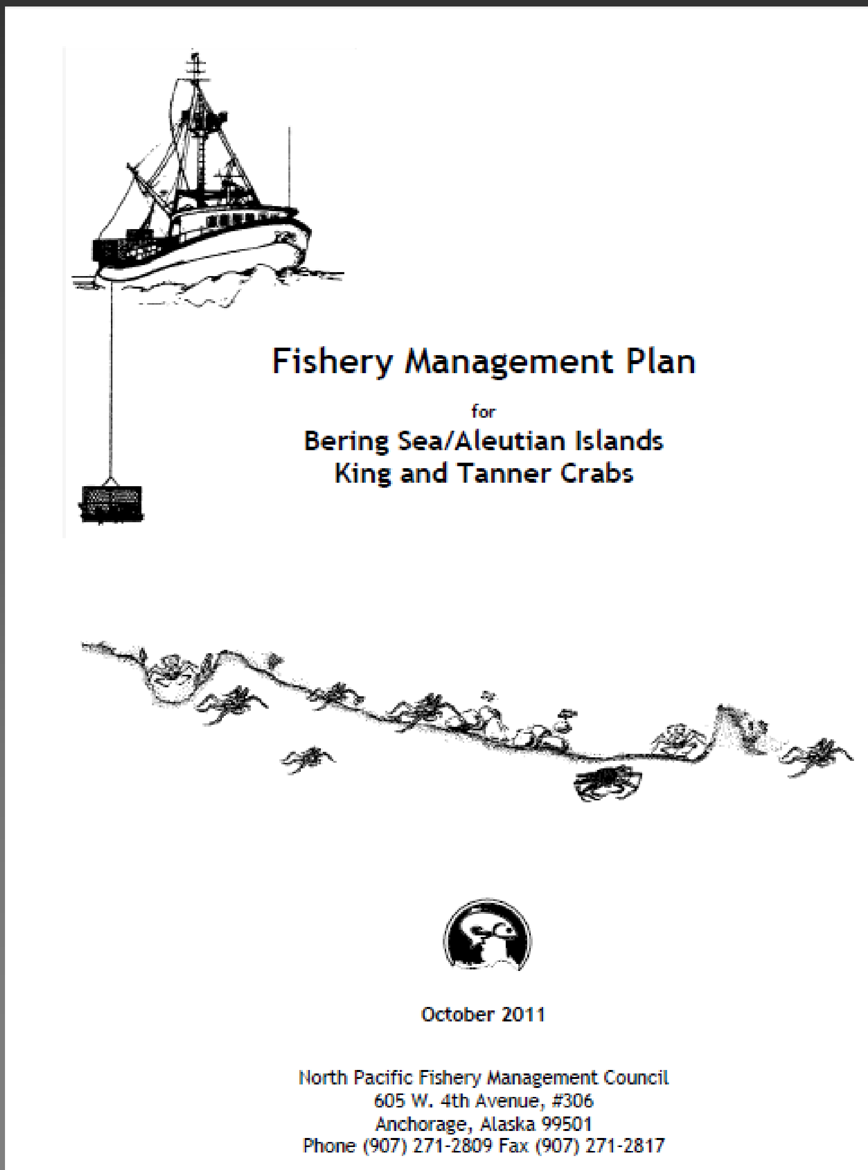
Outline



- Motivation
- Approach
- Life History Considerations
- Results
- Work in Progress
- Closing Thoughts

Motivation


Fishery Management Plan

for

Bering Sea/Aleutian Islands

King and Tanner Crabs

October 2011

North Pacific Fishery Management Council

605 W. 4th Avenue, #306

Anchorage, Alaska 99501

Phone (907) 271-2809 Fax (907) 271-2817

Biological Conservation Objective

Ensure the long-term reproductive viability of king and Tanner populations

Motivation

Large males are important to the fishery and provide the basis for management decisions.

What can measures of mature females and female reproductive potential add to understanding stock productivity?

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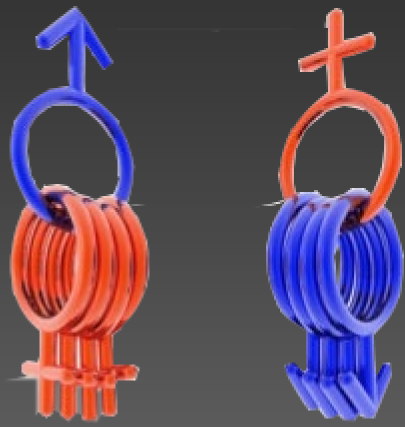
Motivation



Polygamous mating system: both polyandry and polygyny

+

Ability to store sperm

=

Potential reproductive buffer

Motivation

- Impacts of Sex-Selective Harvest
  - Male sperm depletion under intense harvest
    (Pardo et al. 2015, Sato et al. 2005)
  - Reduced fertilization rate and egg clutch size
    (McMullen and Yoshihara 1969, Sainte-Marie et al. 2002, Sato et al. 2005, Sato et al. 2007)
  - Size composition of males participating in mating, mate-guarding time, ejaculate size, agonistic interactions
    (Jivoff 2003, Sainte-Marie et al. 2008, Butler et al. 2015)

Approach

Collect data on females

- ➢ 10-year study (2007 – 2016) across EBS

Fecundity

Female
Sperm Reserves

Approach

Use data from multiple sources to develop understanding of mating dynamics

1. Long-term study
2. Genetics of mating dynamics project
3. NOAA survey data
4. Predictor of male maturity
5. Survey selectivity?

Life History Considerations

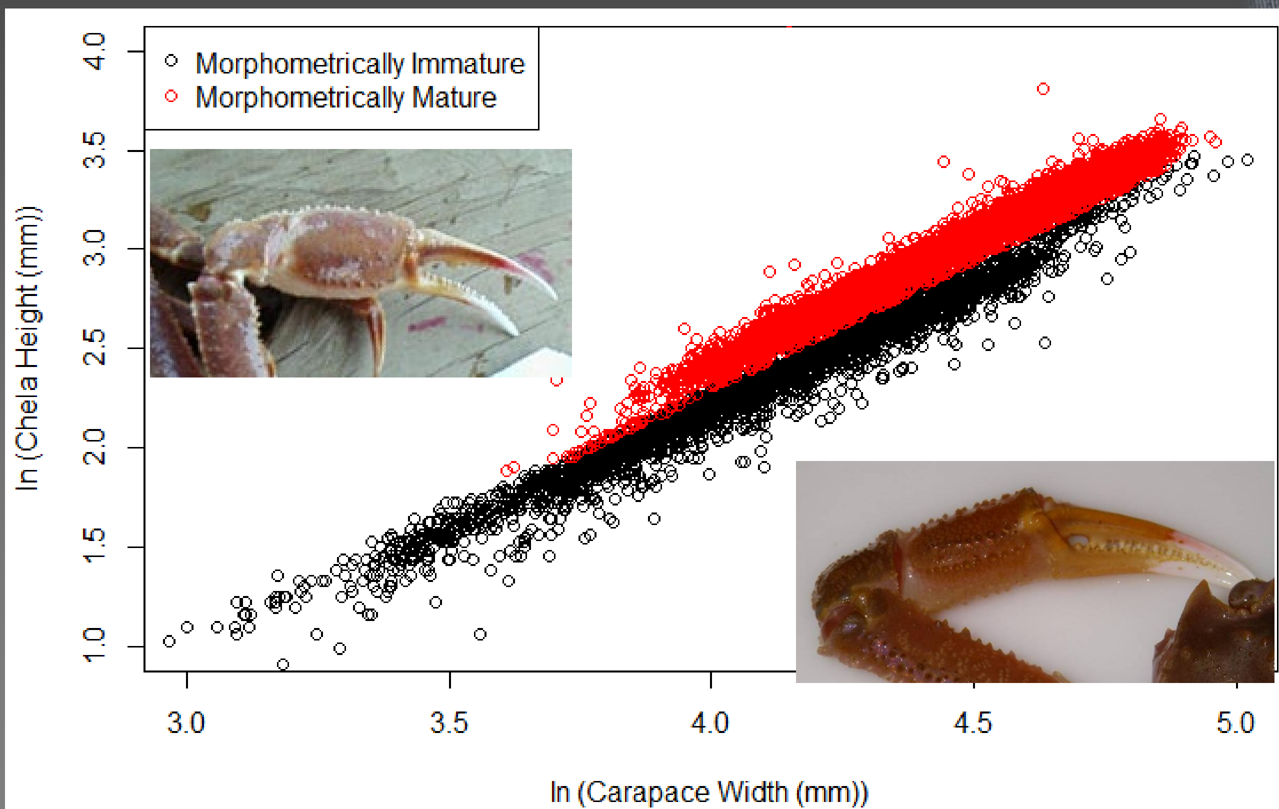
Mating dynamics differ between newly adult (resulting in primiparous clutch) vs subsequent (resulting in multiparous clutch) mating events

Female in soft shell = Male choice

Female in hard shell & mounds = Female choice

Life History Considerations

Terminal molt to adult status results in morphometric changes that must be measured vs visually assessed



adult = morphometrically mature, large claw (competitively superior)

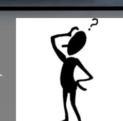
adolescent = physiologically mature

Maturity classification based on cut line equation from Jie:
ln(CH)= -2.8628 + (1.2899 * (LN(CH)))

Life History Considerations

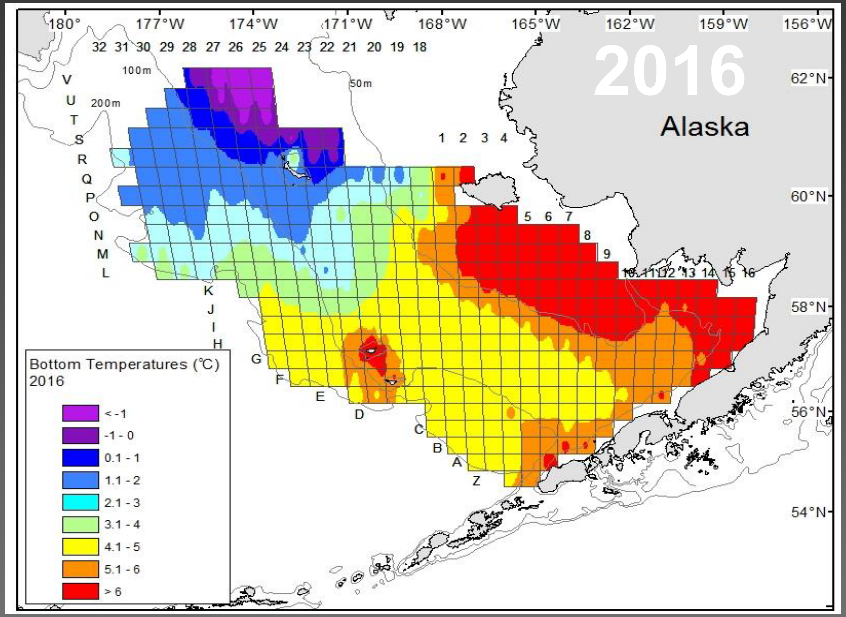
Reproductive status: caution when using shell condition alone

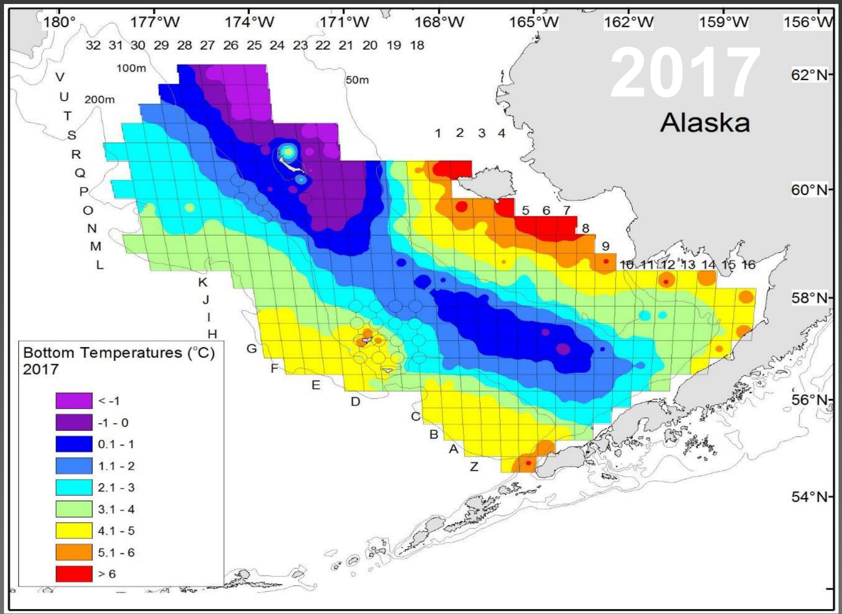
reproductive status	immature	primiparous (annual & 1st year biennial)	primiparous or multiparous (2nd clutch or 2nd year biennial)	multiparous	old multiparous
shell condition	new	new	old	old	very old
approximate years post-maturity		≤1 yr.	2 yr.	~2-4 yr.	4+ yr.



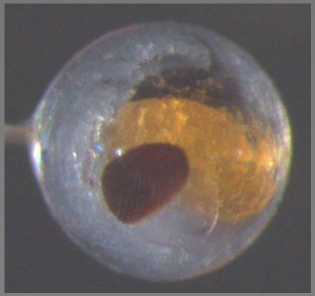
Life History Considerations

Cold pool extent in eastern Bering Sea

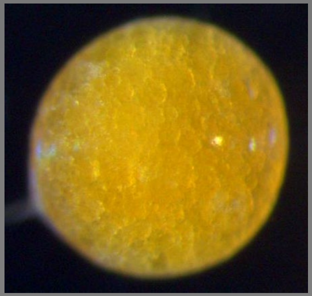




Drives reproductive tempo: annual vs biennial



Example embryos of similar age



Annual @ > 1° C

Biennial @ < 1° C

Life History Considerations

- Sex ratio naturally oscillates
  - ➢ females mature before males from same strong cohorts
  - ➢ primiparous spermathecal load varies with sex ratio in Canada

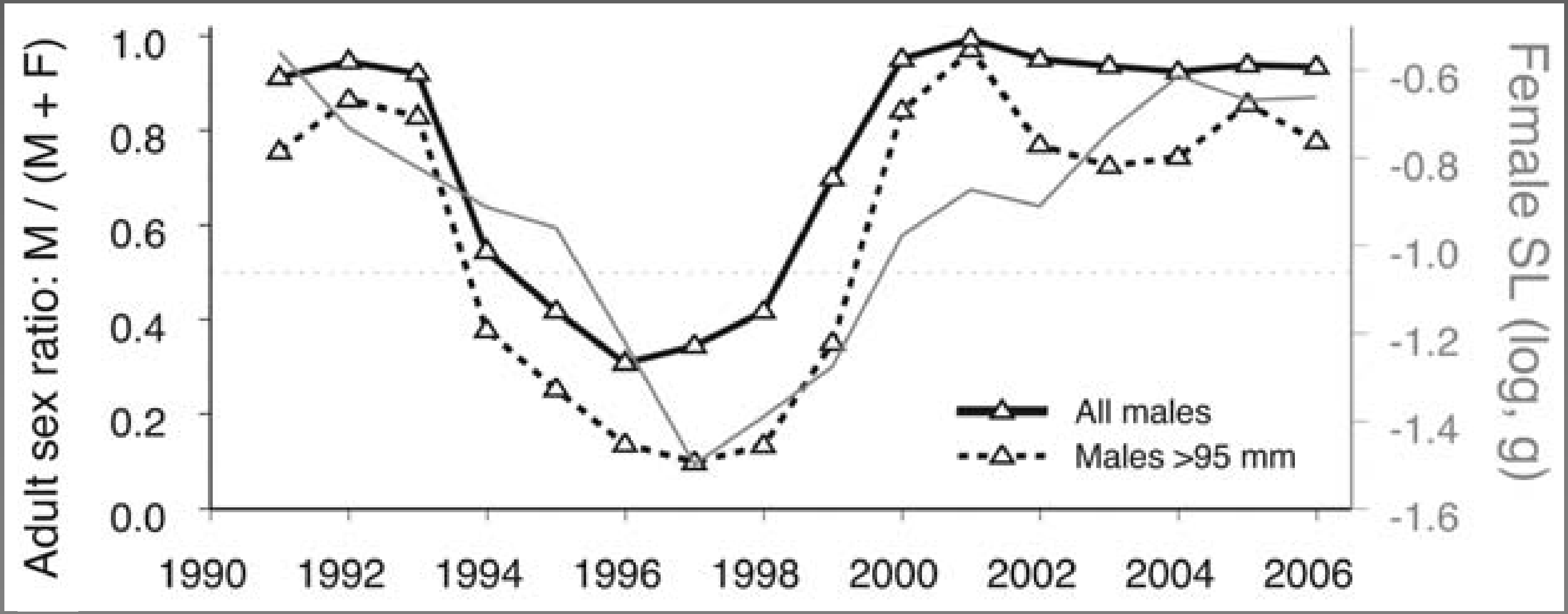
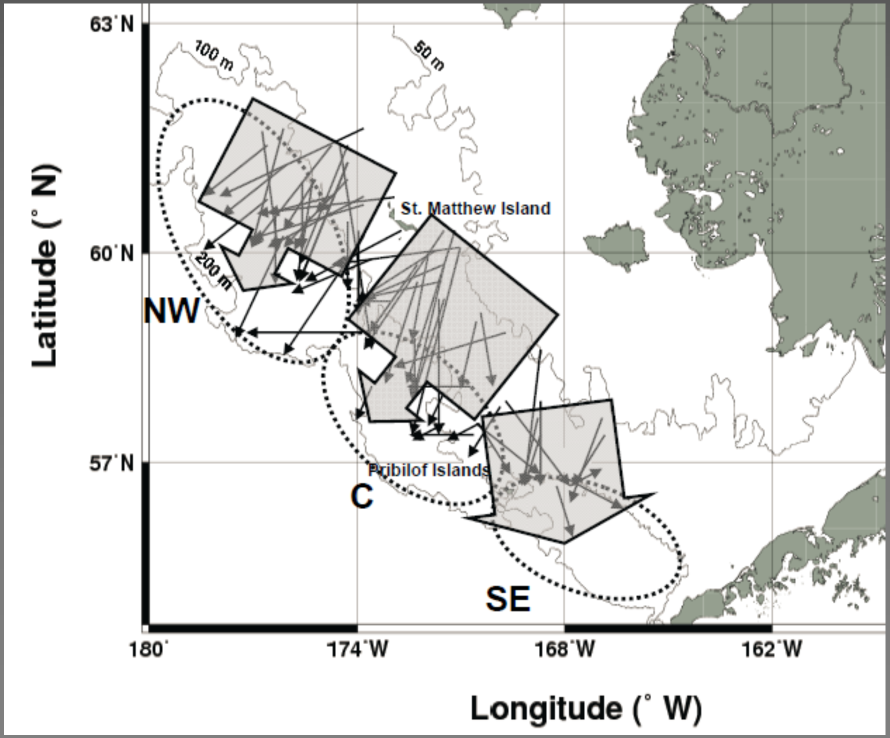


Figure 4 from Sainte-Marie et al. 2008 relative to primiparous females

Life History Consideration

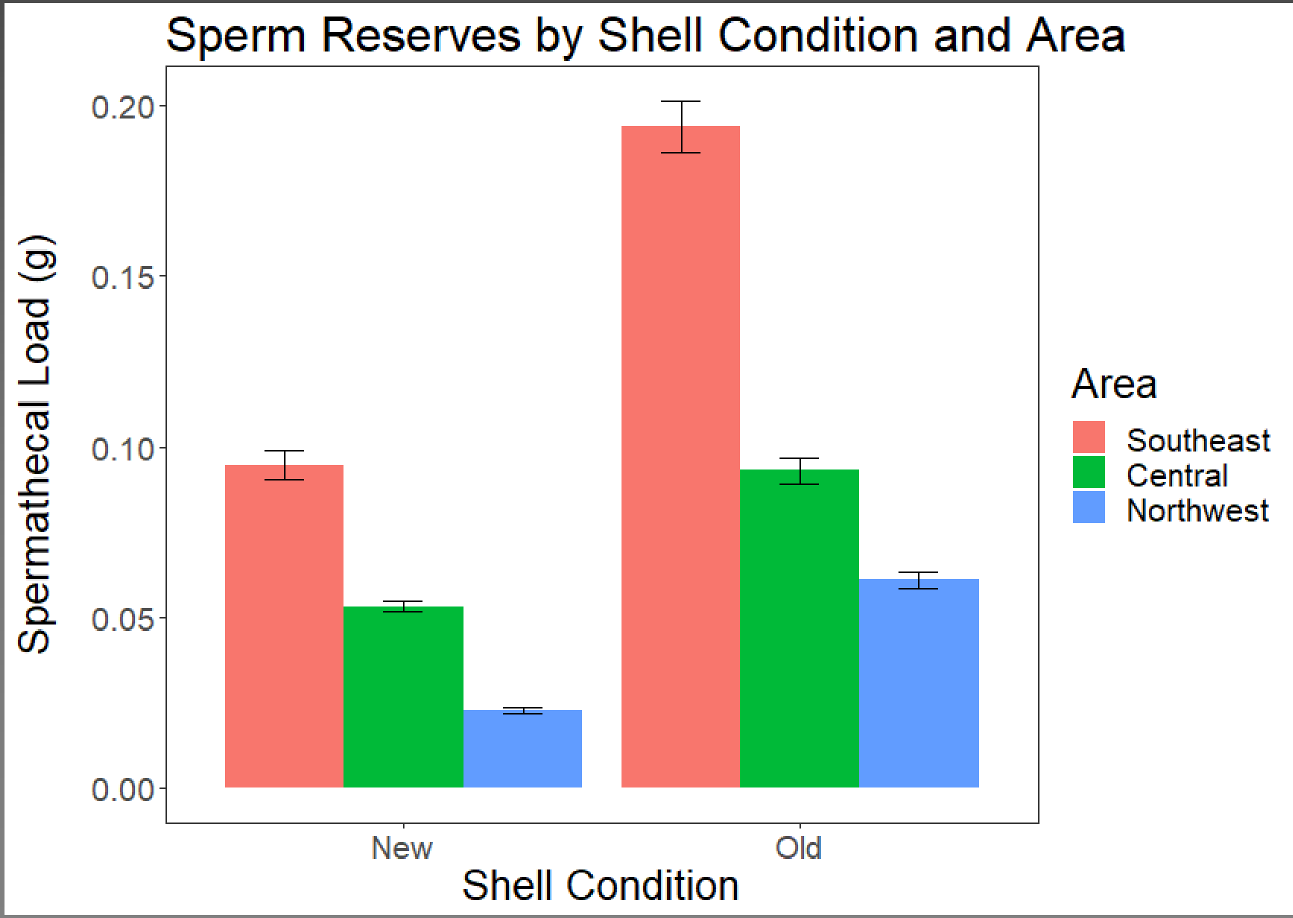
Ontogenetic migration to the SW plus differences in size and age between sexes results in segregated distribution of primiparous females and mature males, likely beyond the range for seasonal migration for mating



Ontogenetic migration shown for females; Parada et al. 2010

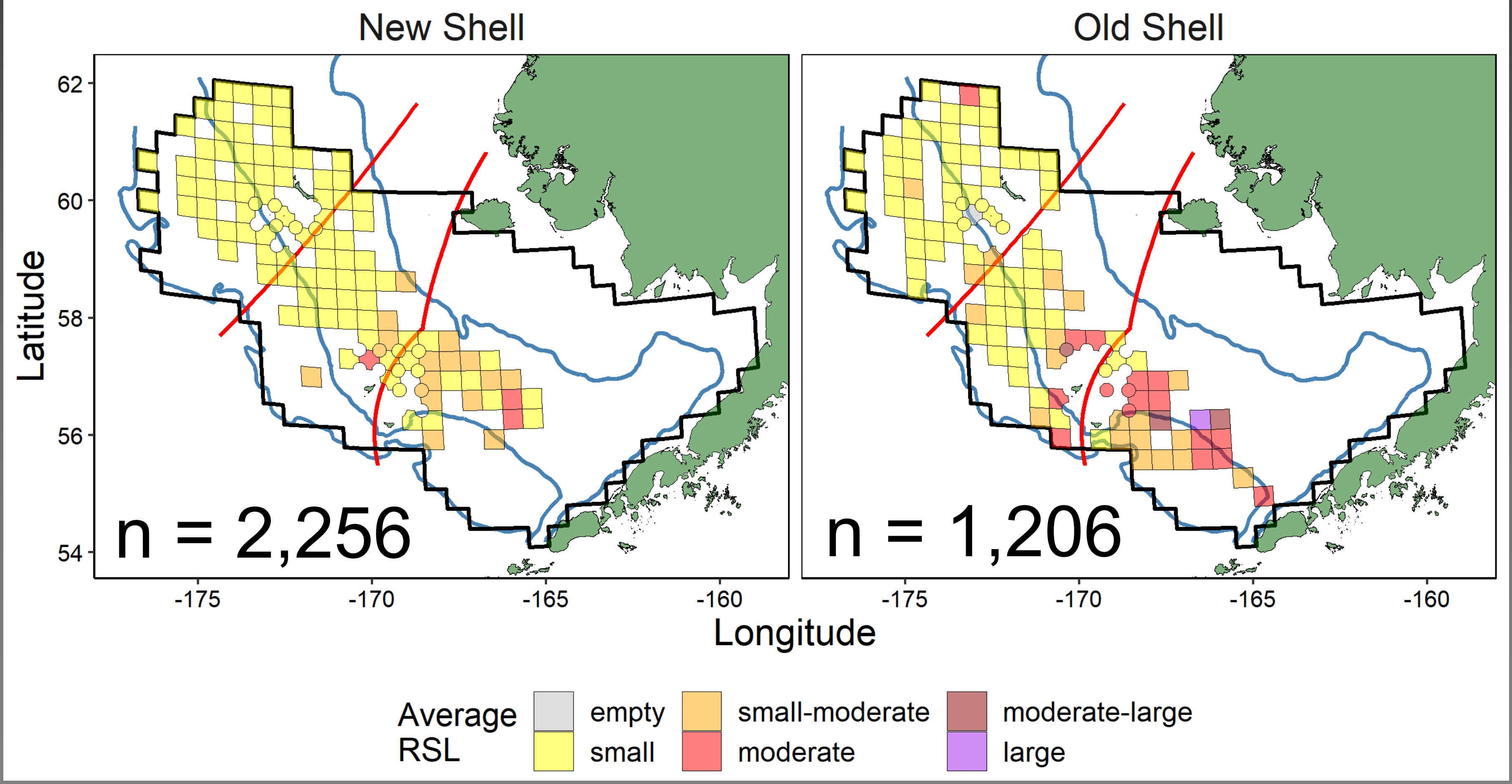
Results

- Variability exists by shell condition groups and areas
- Remating to fertilize subsequent clutches is often necessary & usually occurs



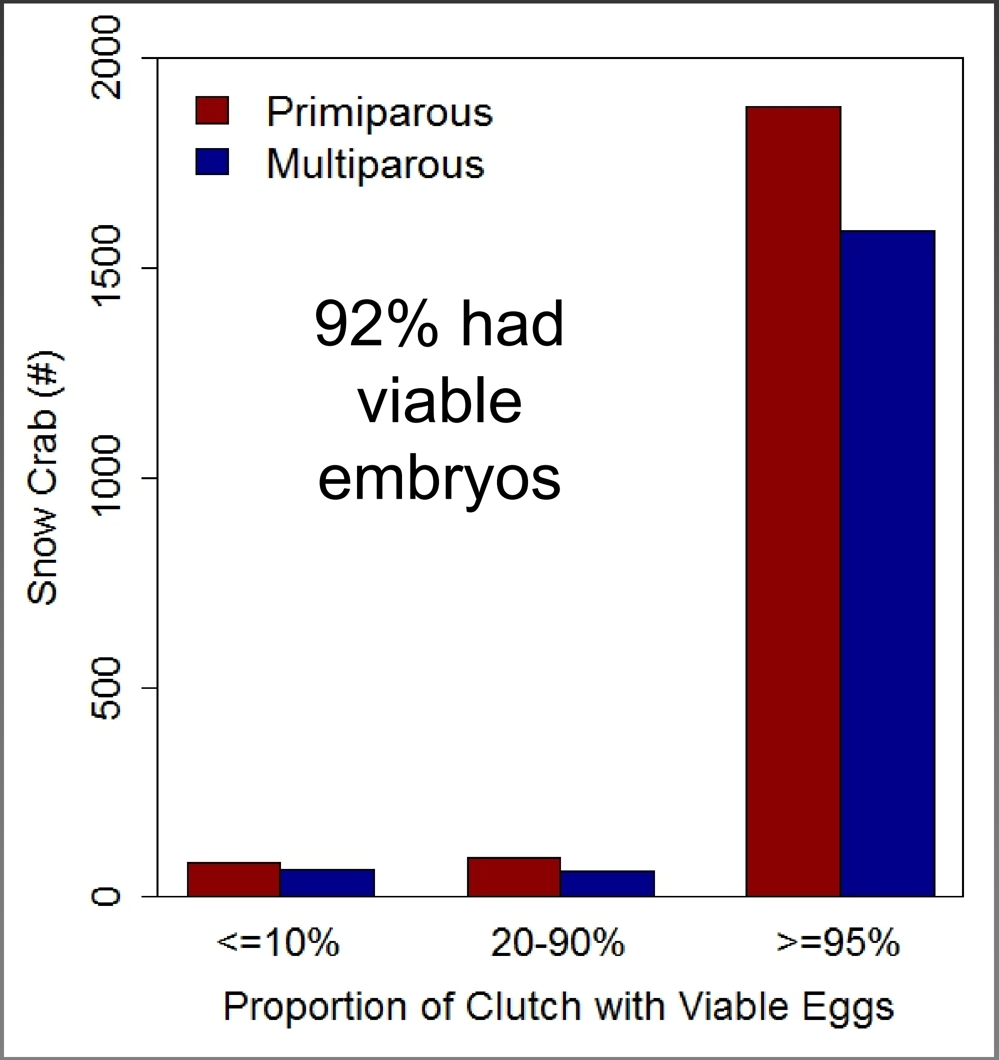
Results

Another view of spatial variability



Results

- No evidence of sperm limitation via unfertilized eggs
- Embryo loss during brooding minimal (Webb et al. 2016)
- Clutch fullness provides a good indication of fertilized egg production (Webb et al. 2016)



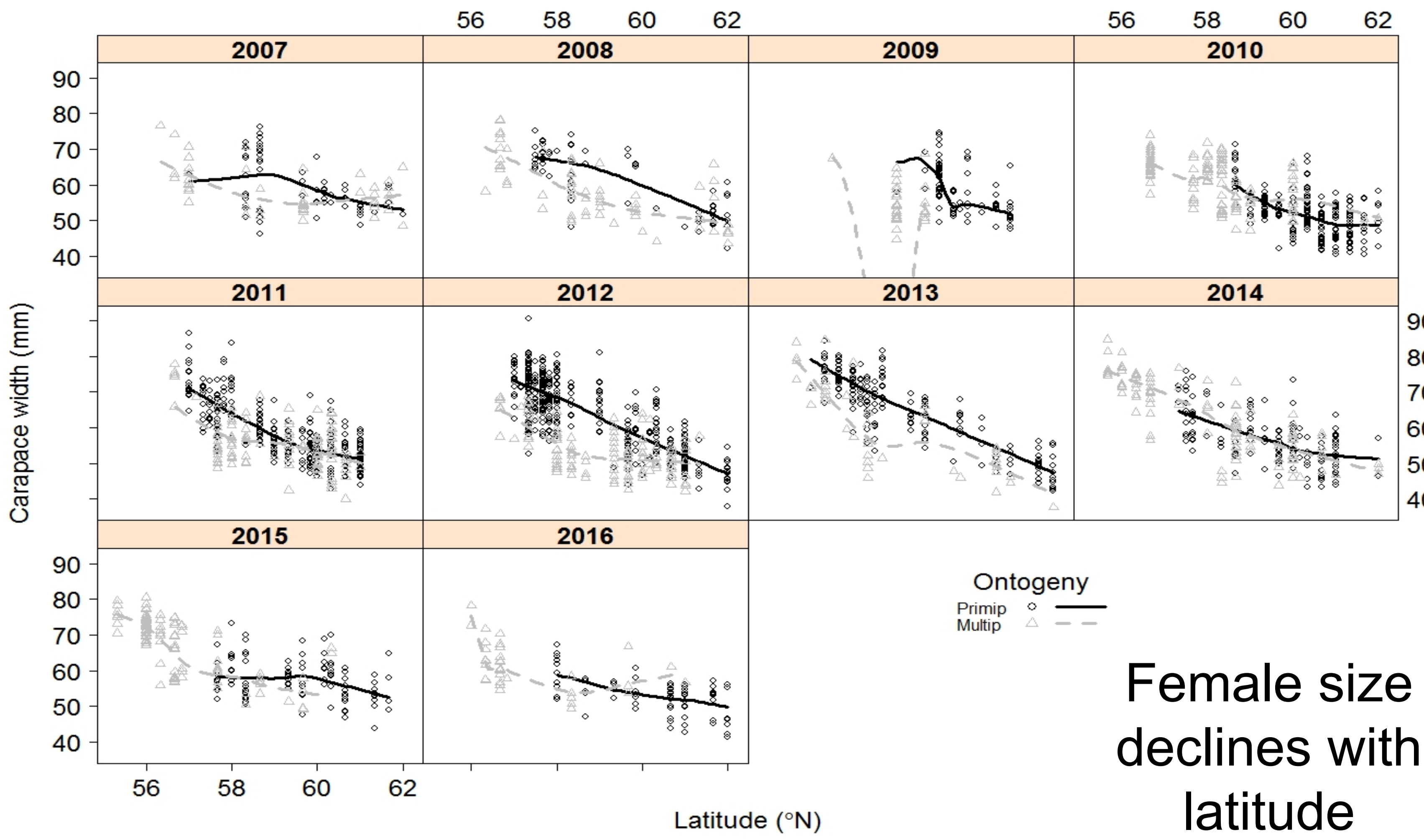
Results

- Correct for female size?

SL increases with female size

Results

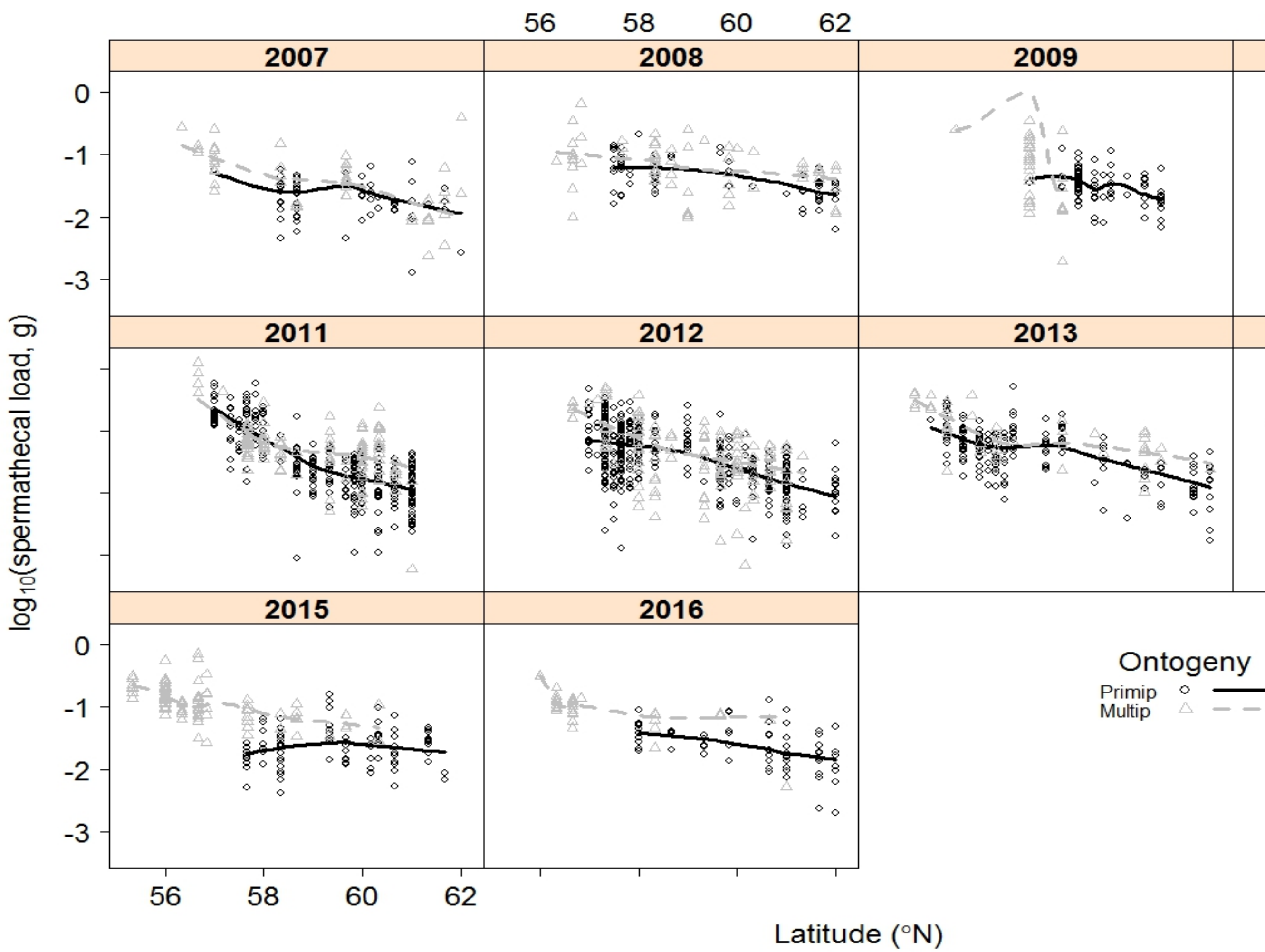
- Correct for female size?



Female size declines with latitude

Results

- Correct for female size?



SL declines with latitude

Results

- Correct for female size?

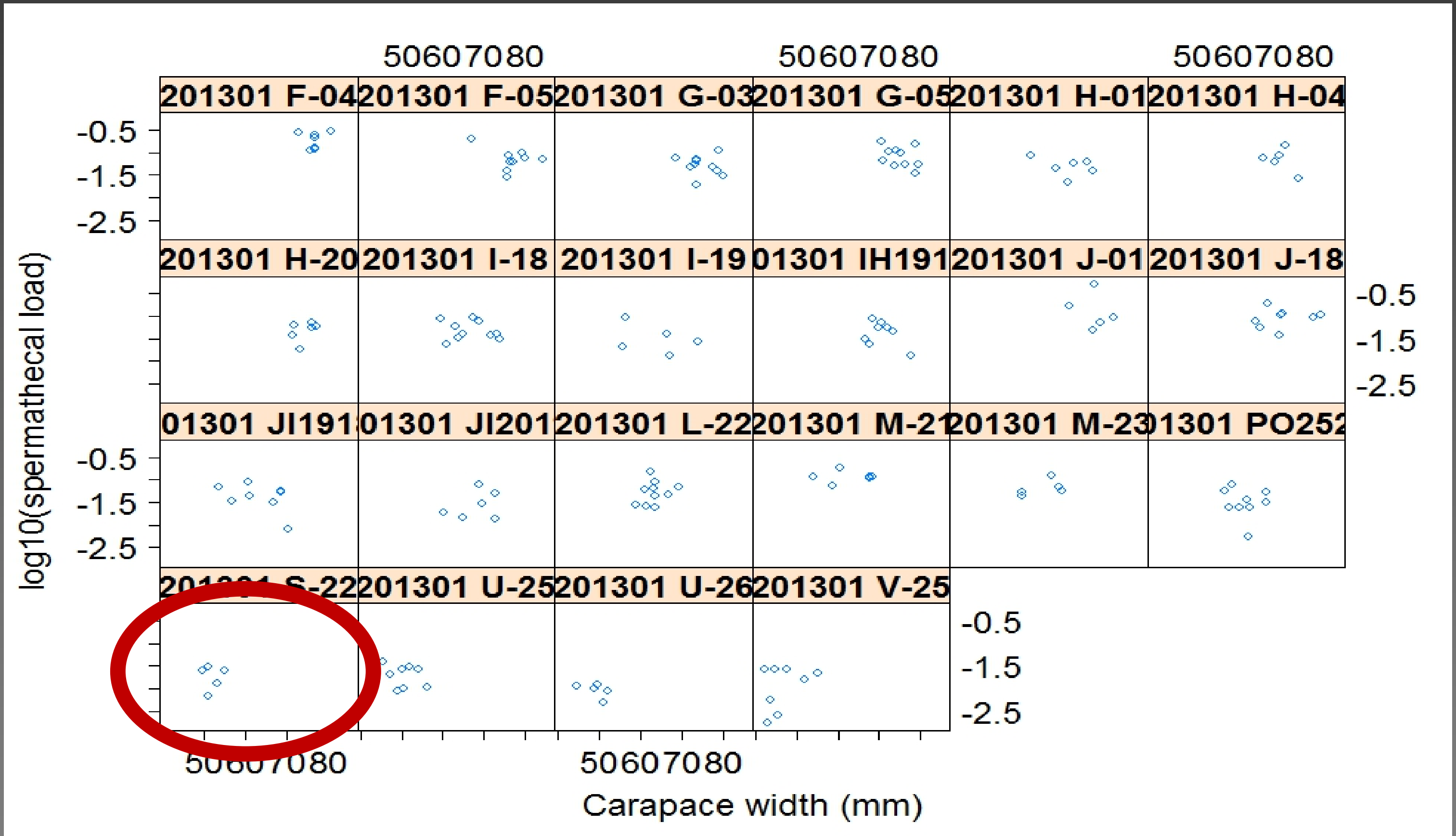
- Possible explanations for female size and SL relationship
  1. selective behavior by males
     - males select and allocate more material to larger females
  2. reflects size composition of available males by latitude
     - since sperm production and allocation varies by male size

Results

- Correct for female size?
- To examine the likelihood of the first explanation, I examined at the station level.
- For primiparous snow crab, examination of linear regression revealed no trend at station level

Results

- Correct for female size?



For example, in 2013, the relationship was significant only at station S-26 (positive) (linear regression, $p \leq 0.05$).

Work in Progress

Development of operational sex ratio

1. Index of species participating in mating
   - Based on genetic work, keep limited to snow crab
2. Index of females participating in mating
   - Separate by shell condition; account for biennial spawning (?)
3. Index of males participating in mating
   - Predictor of male maturity
   - Range of sex ratios that include index of size composition of available males by area

Work in Progress

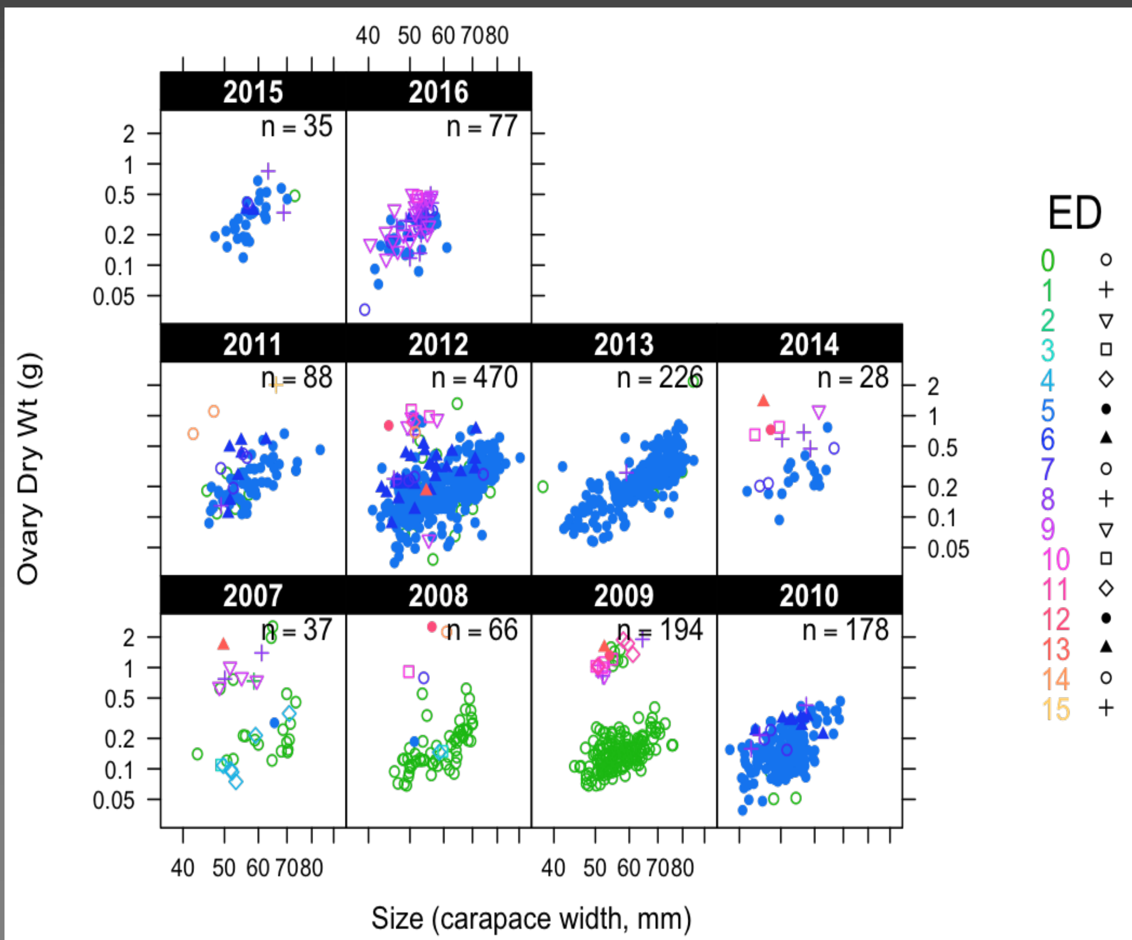
Genetics of mating: number and species of male mates and sires to embryos in the clutch

Most mating occurred between snow crab pairs (98.5%)

+

Work in Progress

Indicator of biennial spawning



- ovary development
- embryo development
- Bottom temperature (though don't know female location in year prior when cue is set)

Work in Progress

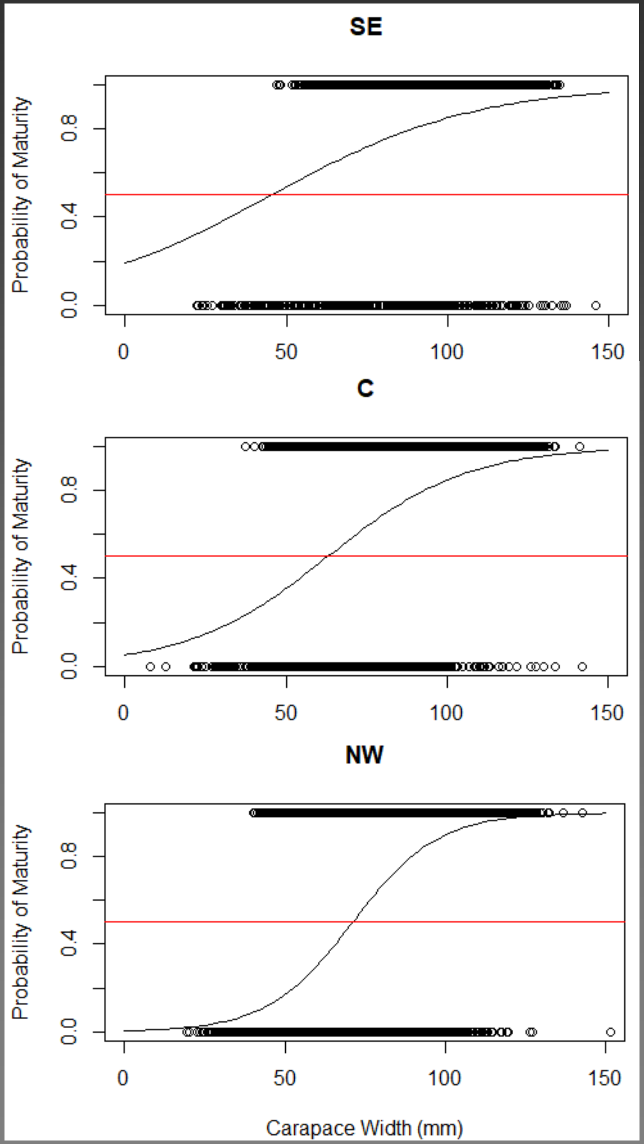
Male size at maturity

Preliminary evaluation of available chela height data showed variable estimates of size at maturity

- Spatial trend opposite of expected & unstable over time

	All Data (n=8901)	2009 (n=1457)	2017 (n=3325)
Combined	67	75	60
SE	46	5	-337
C	63	85	49
NW	71	73	71

- Sensitive to sampling

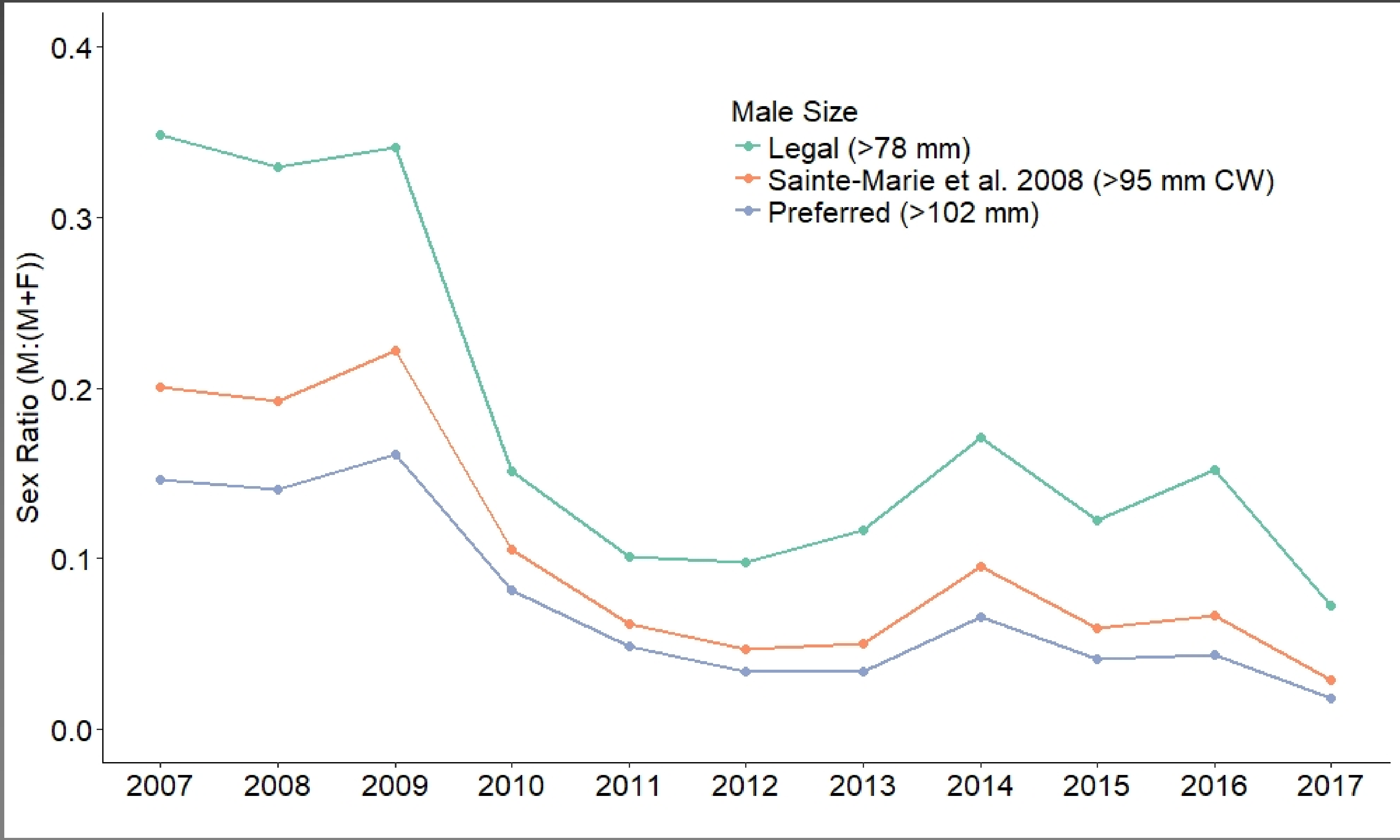


Logistic regressions for all data

Work in Progress

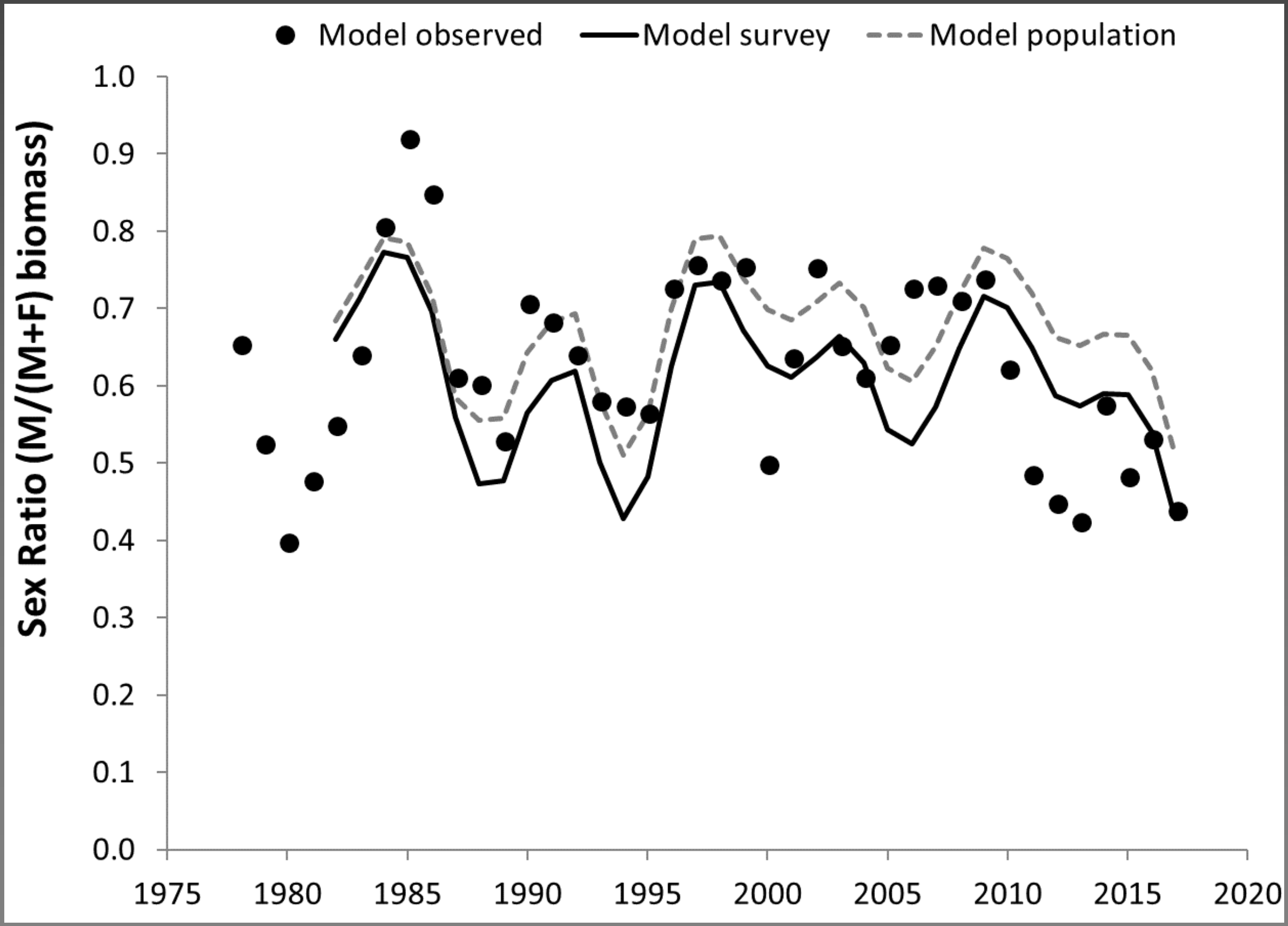
Importance of male size at maturity: vastly affects scale

- although trends are similar



Work in Progress

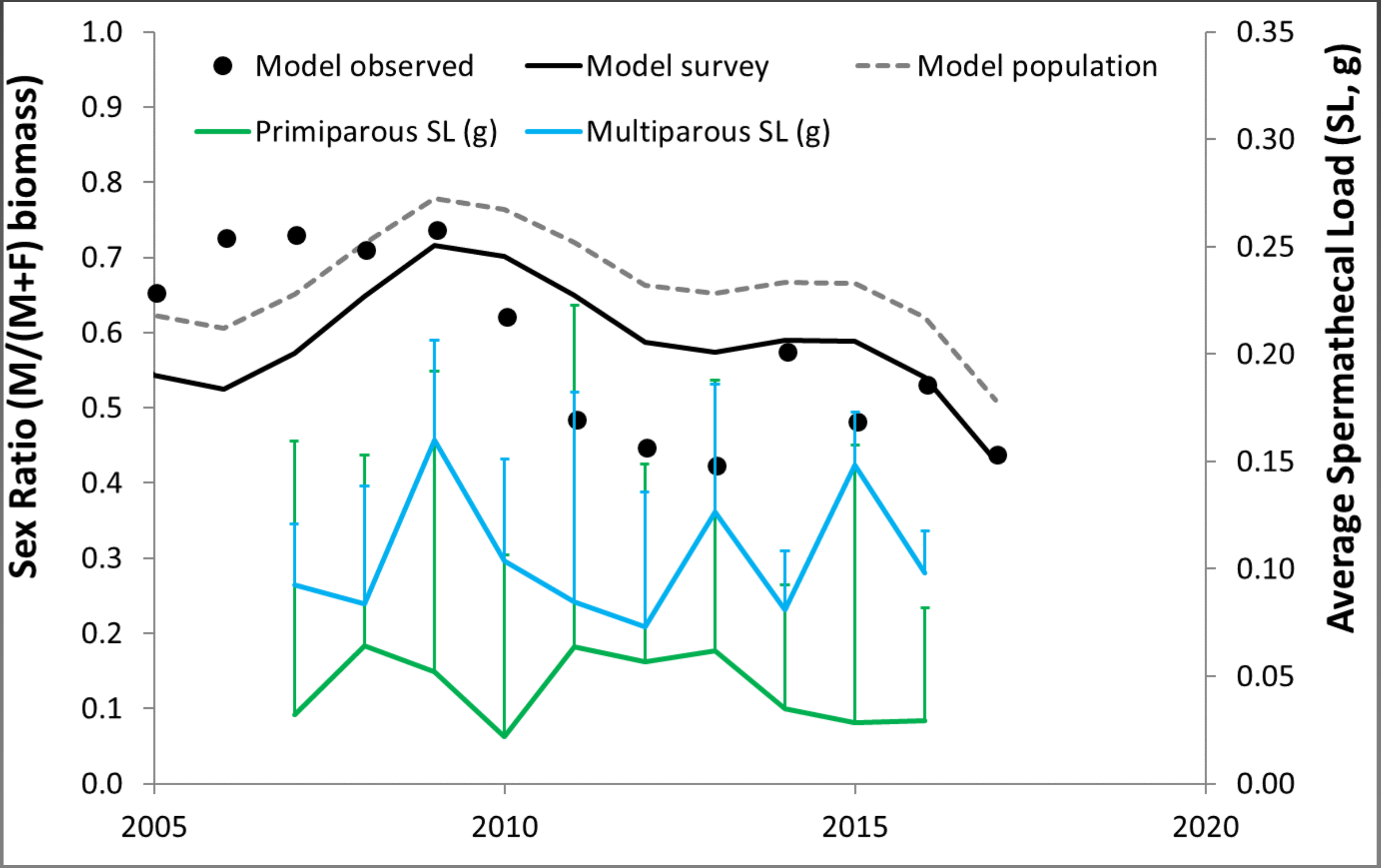
Adult sex ratio based on model estimates from Szuwalski 2018



Work in Progress

Adult sex ratios relative to female sperm reserves

- Examine at finer spatial scale reflecting availability



Closing Thoughts

What have we learned?

- Sperm storage in EBS provides little buffer (remating is necessary)
- No evidence of sperm limitation
- Variability in SL with female size likely reflects size composition and maturity status of available males, which varies across EBS
- Interspecies mating unimportant

Closing Thoughts

Conjectures

- Persistent spatial trend in variability in SL likely reflects size composition and maturity status of available males
- New shell females in northern extent and middle domain likely mate with adolescent males

Closing Thoughts

What have we think may be important factors for Bering Sea mating dynamics?

- LOCATION
  - Large spatial scale and segregation of adult males and primiparous females
  - How will this change with shifting distribution in response to environmental change?
    - Hypothesis of Lobo Orensanz & collaborators: adult males don’t matter to stock productivity
- TEMPERATURE
  - Biennial spawning

Many Helping Hands

Those who currently work on this project

Julia Dissen & Bill Gaeuman
Collaborators: Wei Cheng, Ben Daly, Zac Grauvogel, Chris Habicht, Stew Grant, Joel Webb
Laura’s graduate committee: Gordon Kruse, Ginny Eckert, Franz Mueter, Bernard Sainte-Marie, and Doug Pengilly

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