

Reproductive Biology Informs Fishery Management of Snow and Tanner Crabs in the Eastern Bering Sea

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Tanner Crab Density in 2017

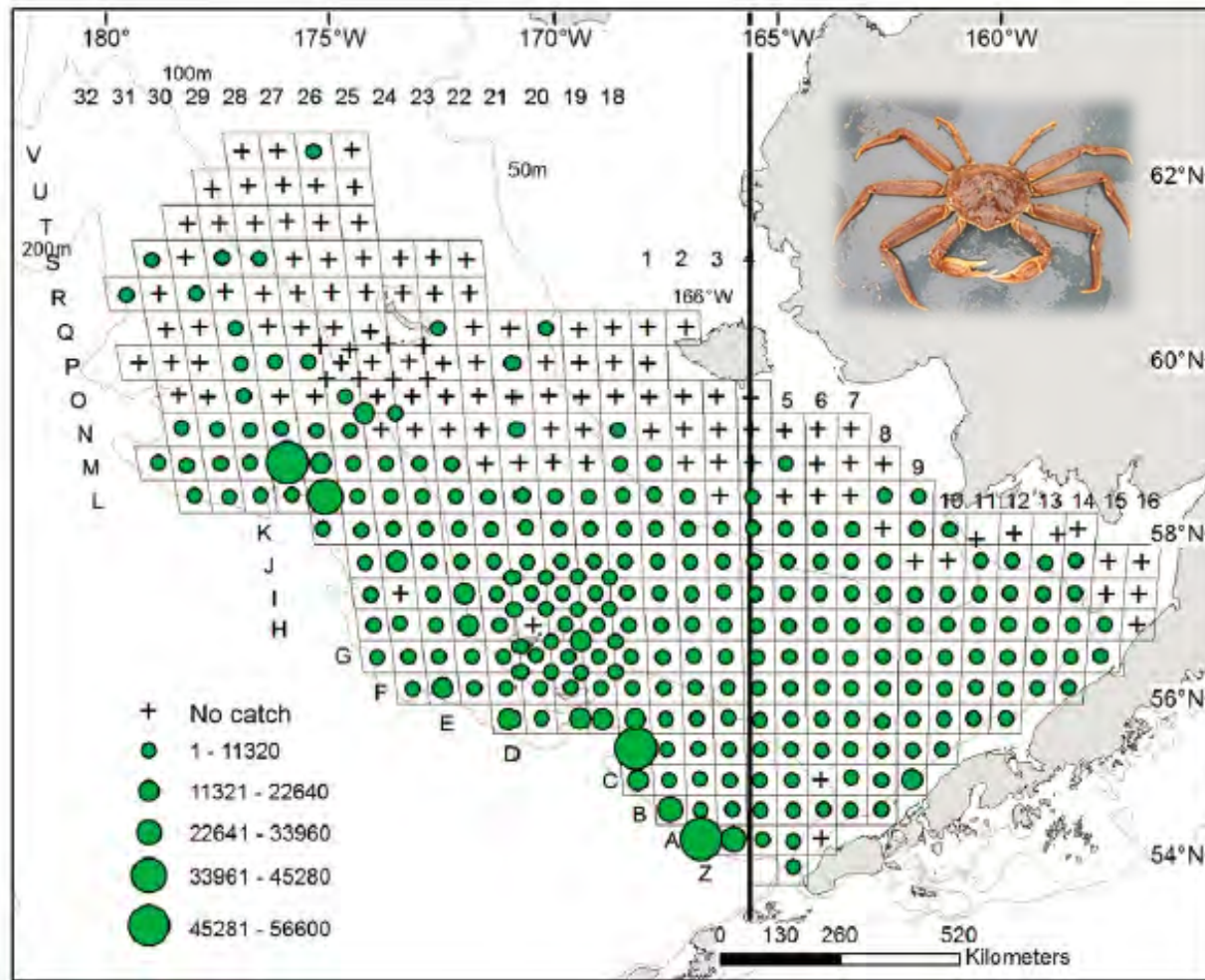


Figure 51. -- Total density (number nm^{-2}) of Tanner crab (*Chionoecetes bairdi*) at each station sampled in 2017.

Snow Crab Density in 2017

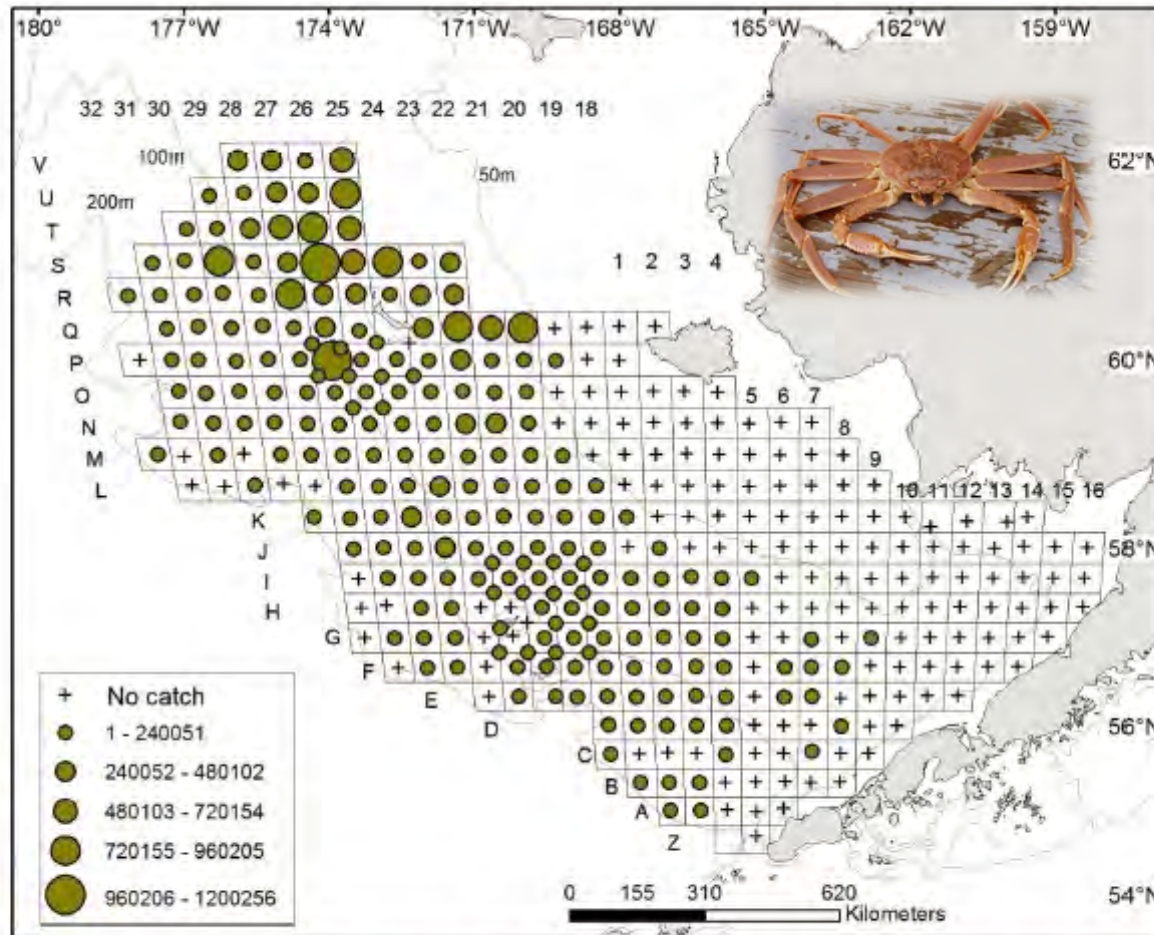


Figure 67. – Total density (number nm^{-2}) of snow crab (*Chionoecetes opilio*) at each station sampled in 2017. Data depicted by circles are equal interval densities.

Snow-Tanner Hybrid Density in 2017

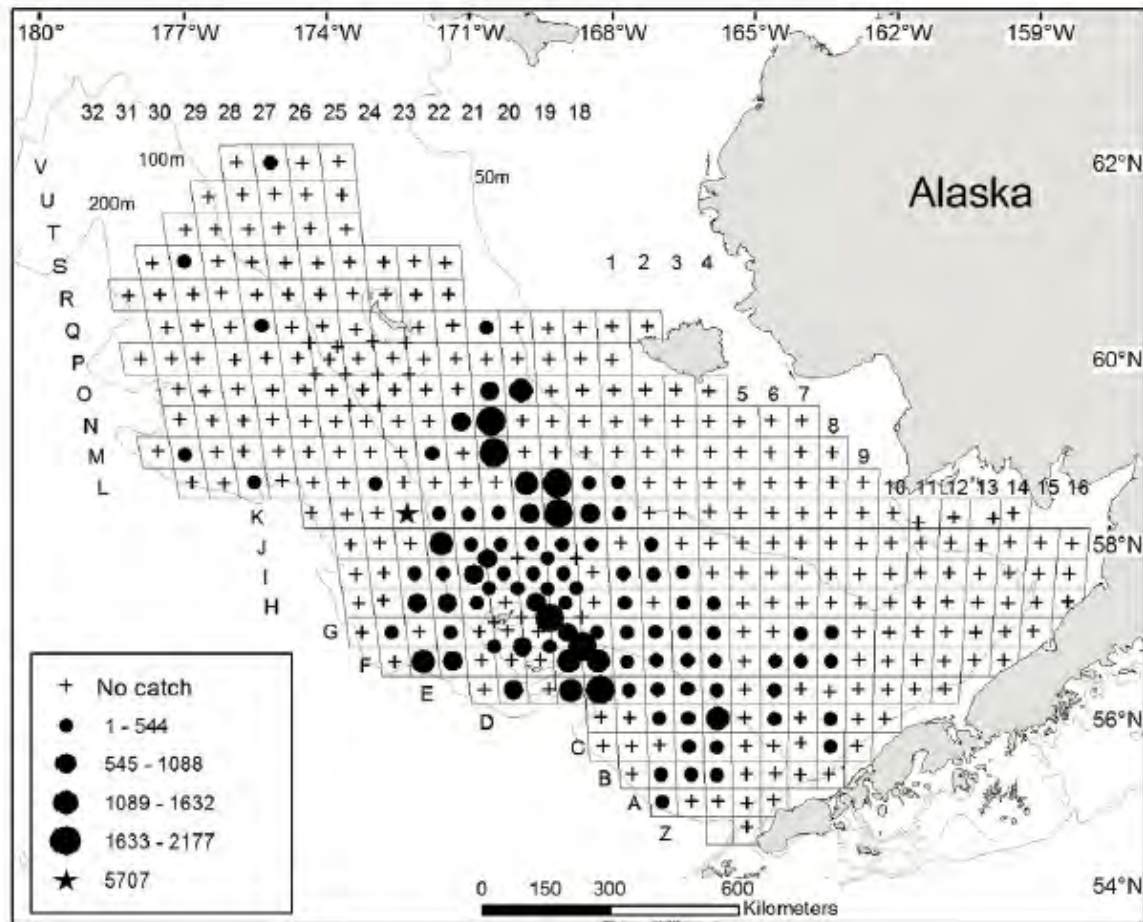
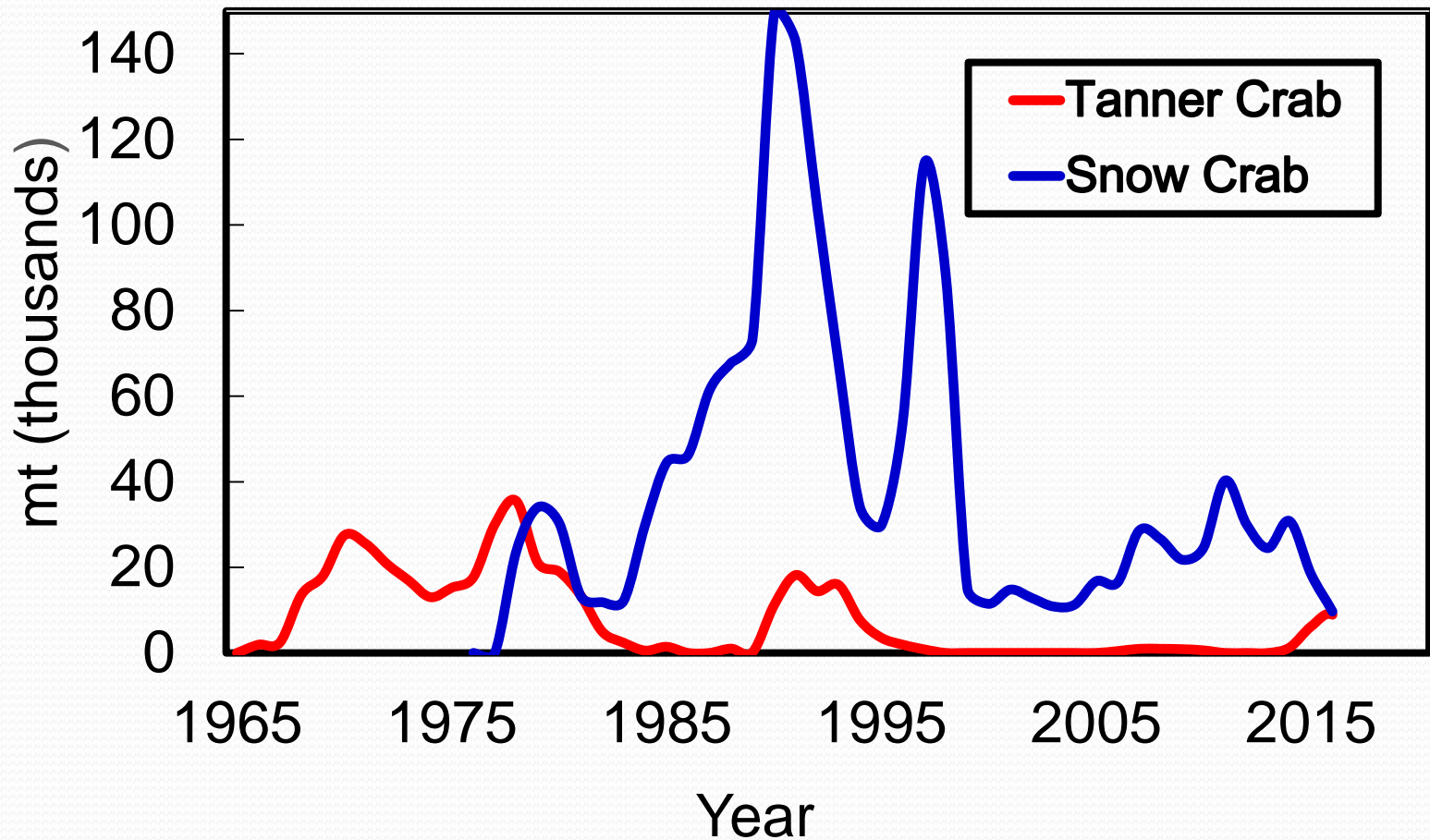


Figure 78. – Total density (number nm^{-2}) of *Chionoectes* spp. hybrid crab at each station sampled in 2017. Data depicted by circles are crab densities at equal intervals.

Lang et al. (2017)

EBS Snow and Tanner Crab Harvests



Motivating Questions

- What drives boom-bust patterns in crab stocks and harvests?
 - Oceanography
 - Ecology (predation)
 - Population dynamics
- What is the role of reproductive biology?
- Do large male-only harvests compromise female reproductive potential and stock productivity?

Ultimate Goal

→ Improve fishery management & outcomes

Reproductive Biology of *Chionoecetes*

- **Determinate growth** – terminal molt to maturity
- Indicators of terminal molt: ♀ – Abdomen size
♂ – Claw size



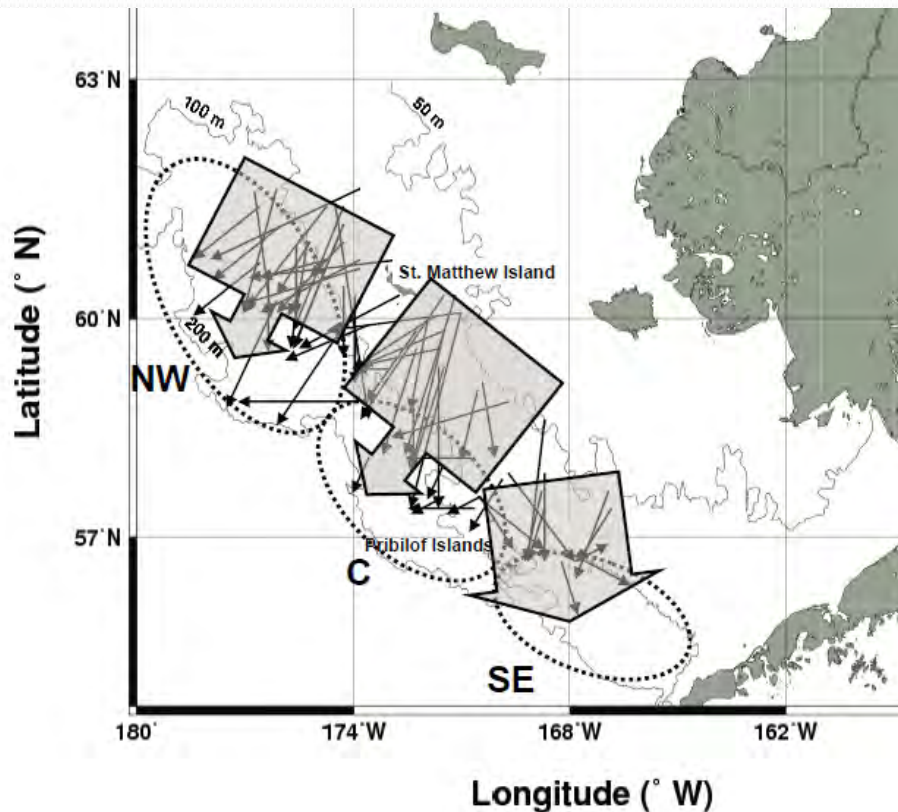
- Shell Condition – “age” relative to terminal molt

Terminology – Females

Shell Condition		Newshell (SC2)	Oldshell (SC3)	Very Oldshell (SC4-5)
Reproductive status	Immature	Primiparous	Multiparous	Multiparous
Approximate years post-maturity		$\leq \sim 1$ yr.	$\sim 2-4$ yr.	4+ yr.

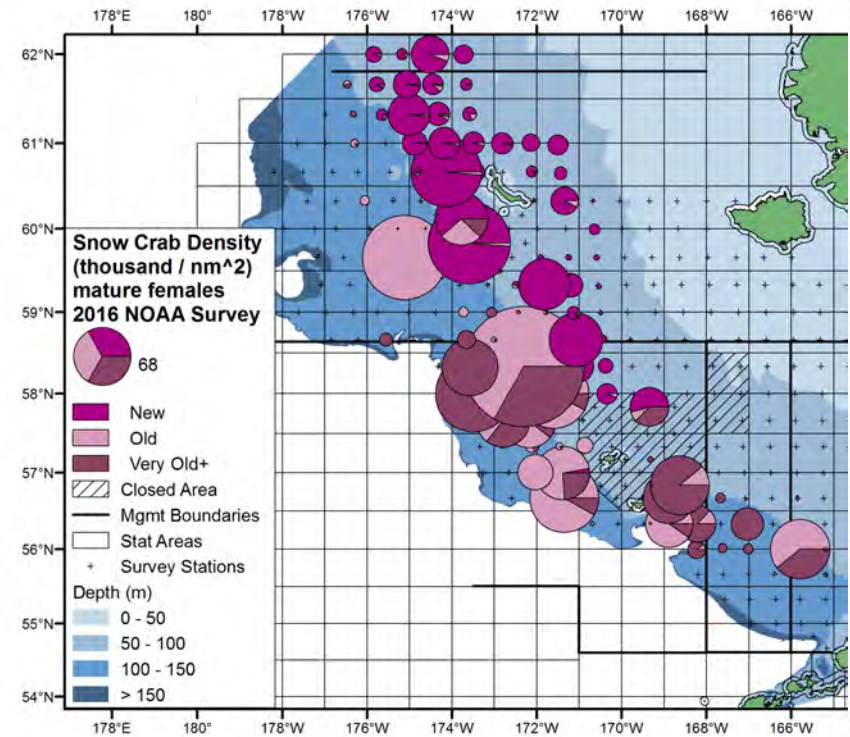


Ontogenetic Movements of Snow Crab



Ontogenetic female migration

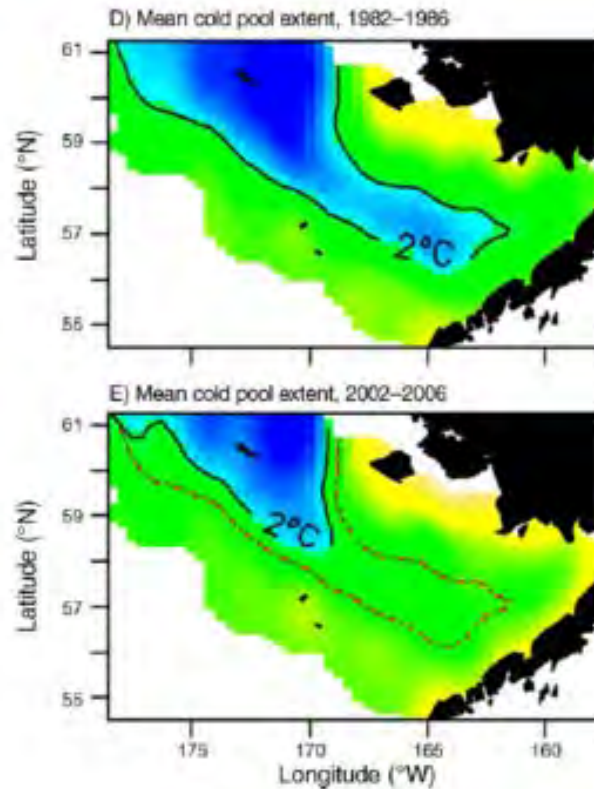
Parada et al. (2010)



Female segregation
by shell condition

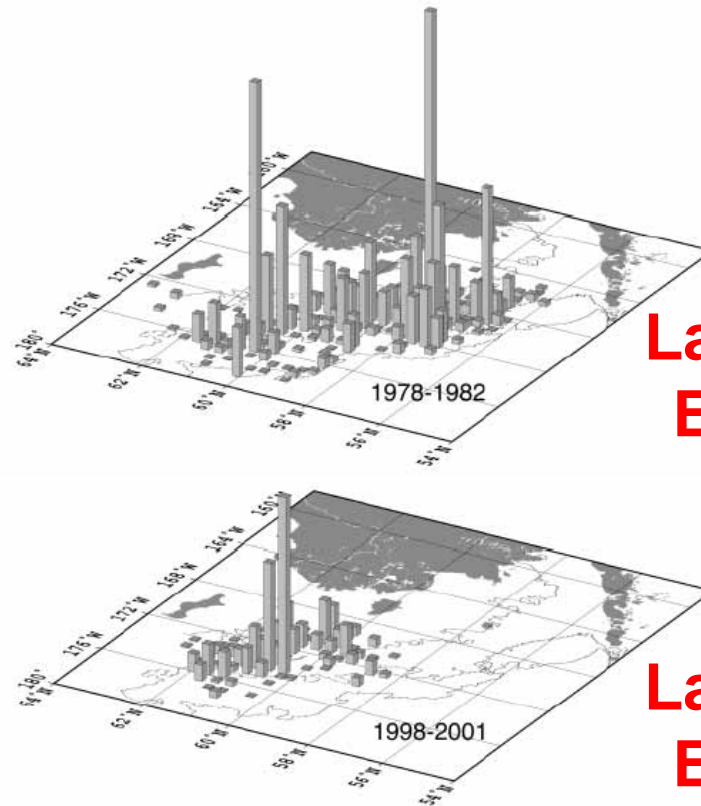
Slater et al. (in prep.)

Shifts in Distribution of Snow Crab



Shift in bottom cold pool

Mueter & Litzow (2008)



Late 70s & Early 80s

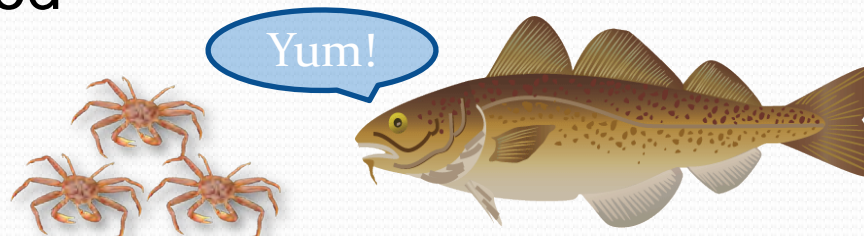
Late 90s & Early 00s

Shift of males to NW

Orensanz et al. (2004)

Environmental Ratchet Hypothesis (Orensanz et al. 2004)

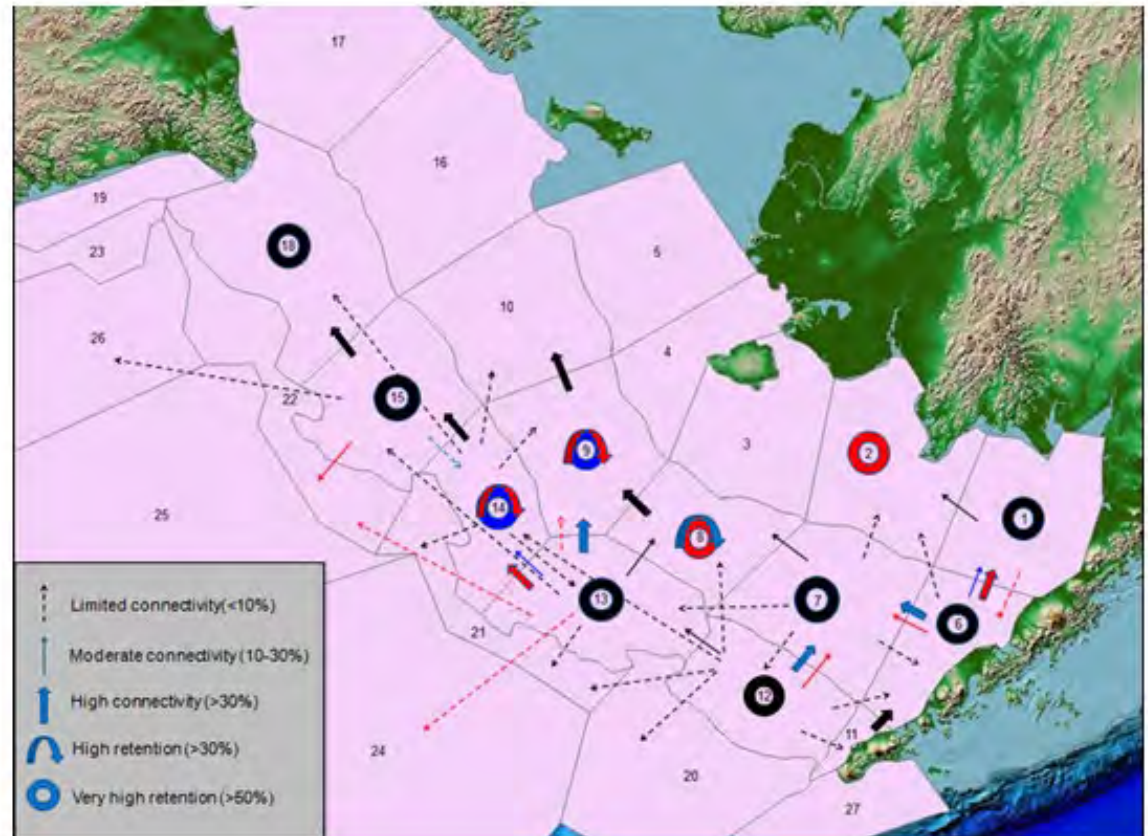
- Over last 3+ decades, snow crab distribution has contracted to the north
- Shift is associated with warming and contraction of bottom cold pool (≤ 2 C)
- Cool periods did not result in return shift south
 - Currents carry larvae to the NW (ROMS)
 - Southern boundary may be constrained by predation by Pacific cod



Ecology of Tanner Crab

Richar et al. (2015)

- ROMs shows that Bristol Bay depends on local retention
- Retention in Pribilof Islands increased in 1990s

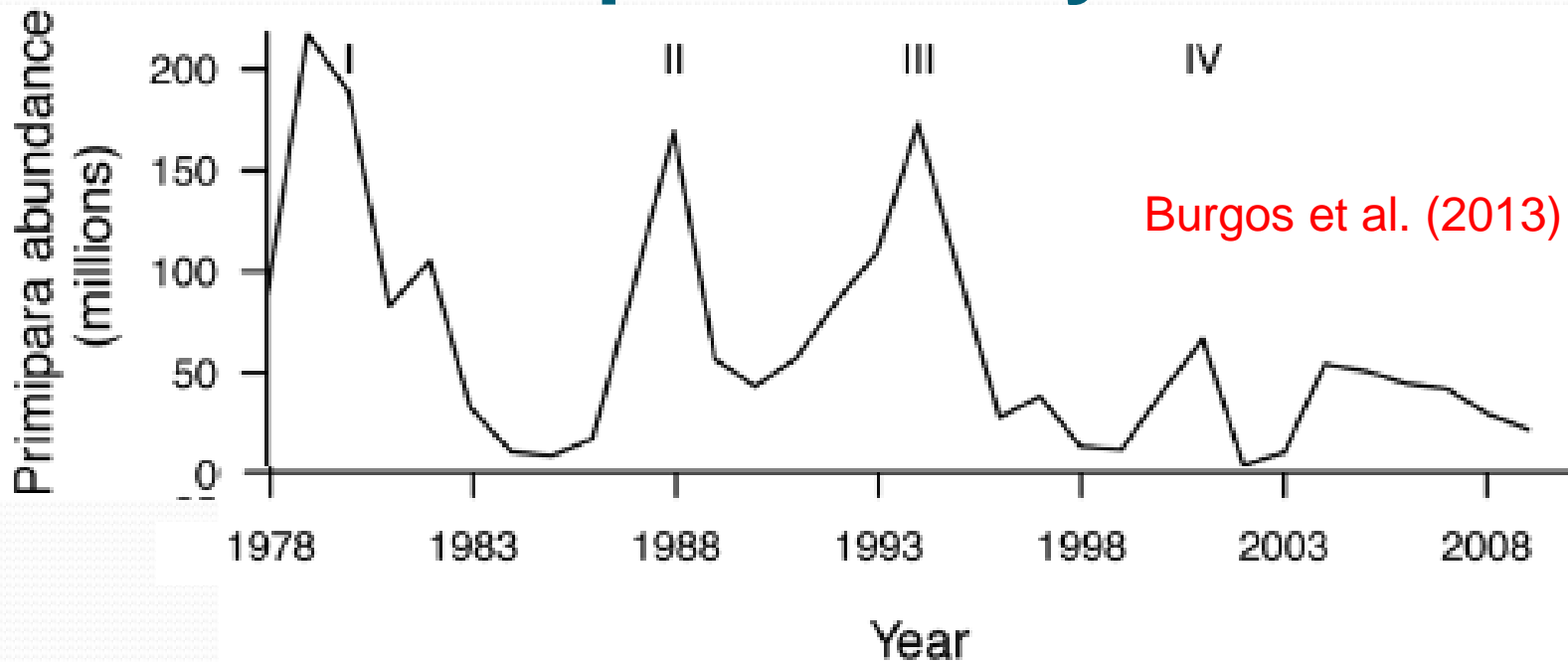


Black = retention (full period)

Red = retention (1978 – 1990)

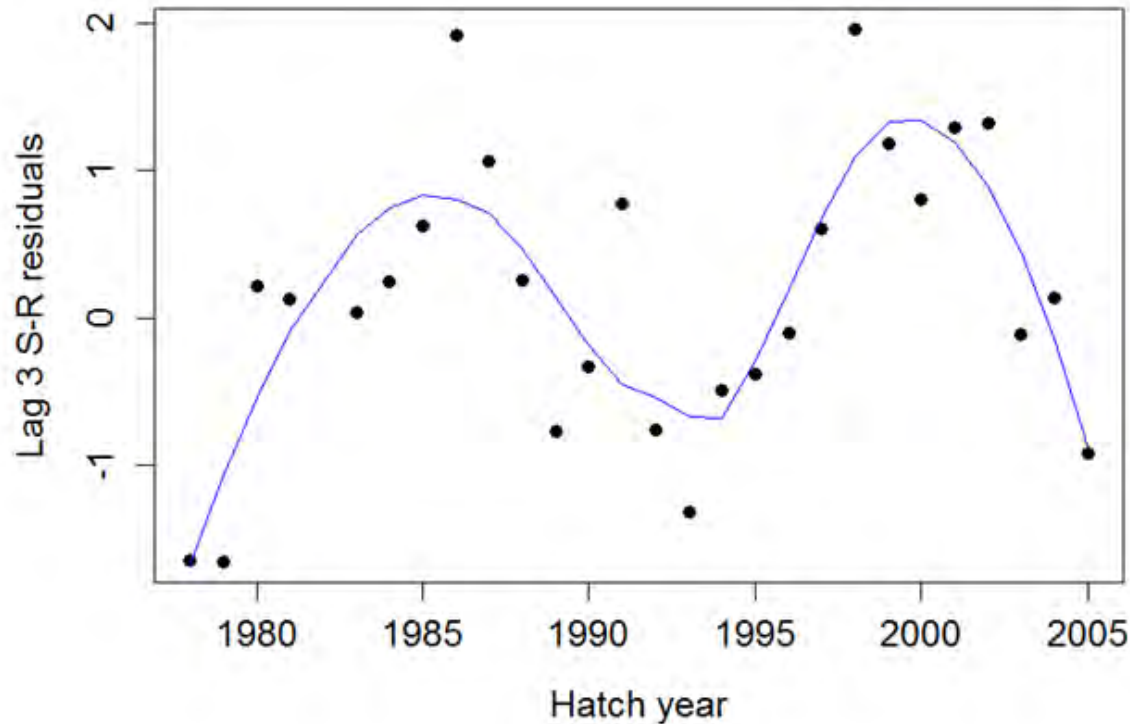
Blue = retention (1991 – 2004)

Snow Crab Population Cycles



- Recruitment with periodicity of ~ 7 yr ($\sim 1T$)
- **Cohort resonance** – greater sensitivity of populations to environmental variability on time scales near one generation time; variability increases with fishing

Tanner Crab Population Cycles



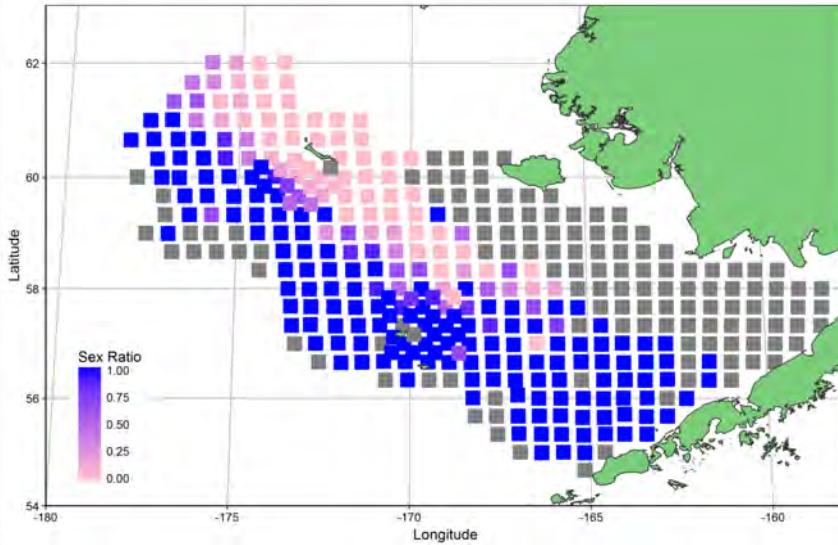
Richar et al. (2015)

- Recruitment residuals of period 13-14 yr ($\sim 2T$)
- **Over-compensatory density-dependent recruitment** (recruitment declines with increasing stock size); unstable cycles

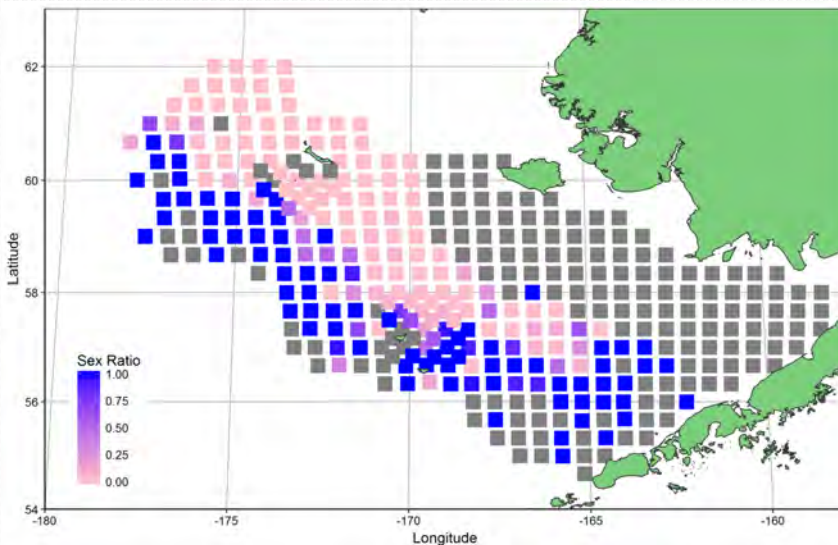
Reproductive Biology of Tanner and Snow Crab

- In Bristol Bay, Tanner crab reach 50% maturity by:
 - 104.4 mm Carapace Width (CW, newshell males)
 - 74.6 mm CW (newshell females)
- In EBS, snow crab reach 50% maturity by:
 - 65 mm CW (newshell males)
 - 50 mm CW (newshell females)
- Owing to sexual dimorphism in size and age at maturity, there are natural large, asynchronous fluctuations in adult sex ratio

Variation in Operational Sex Ratio



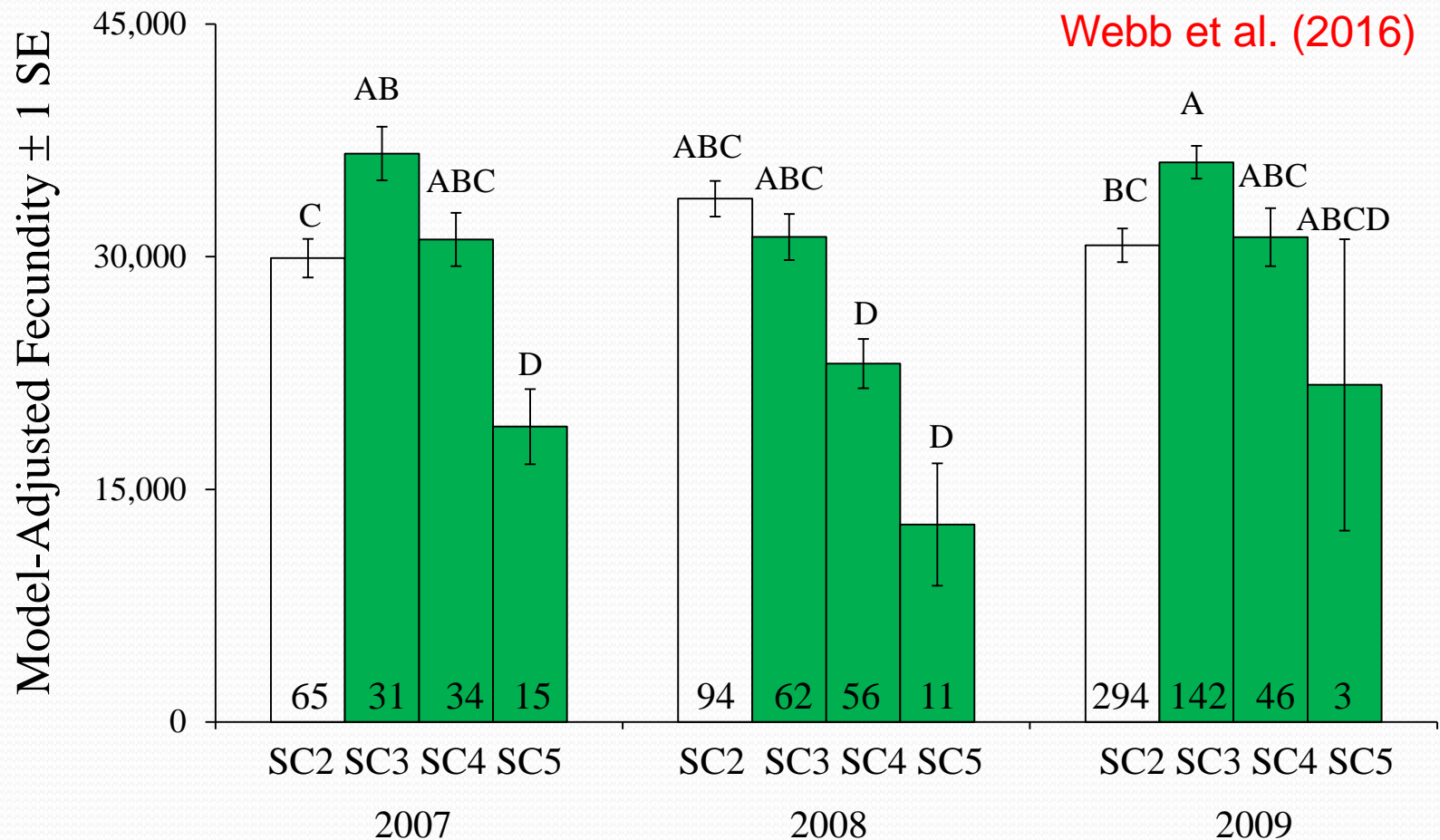
2009 – **male** dominated



2013 – **female** dominated

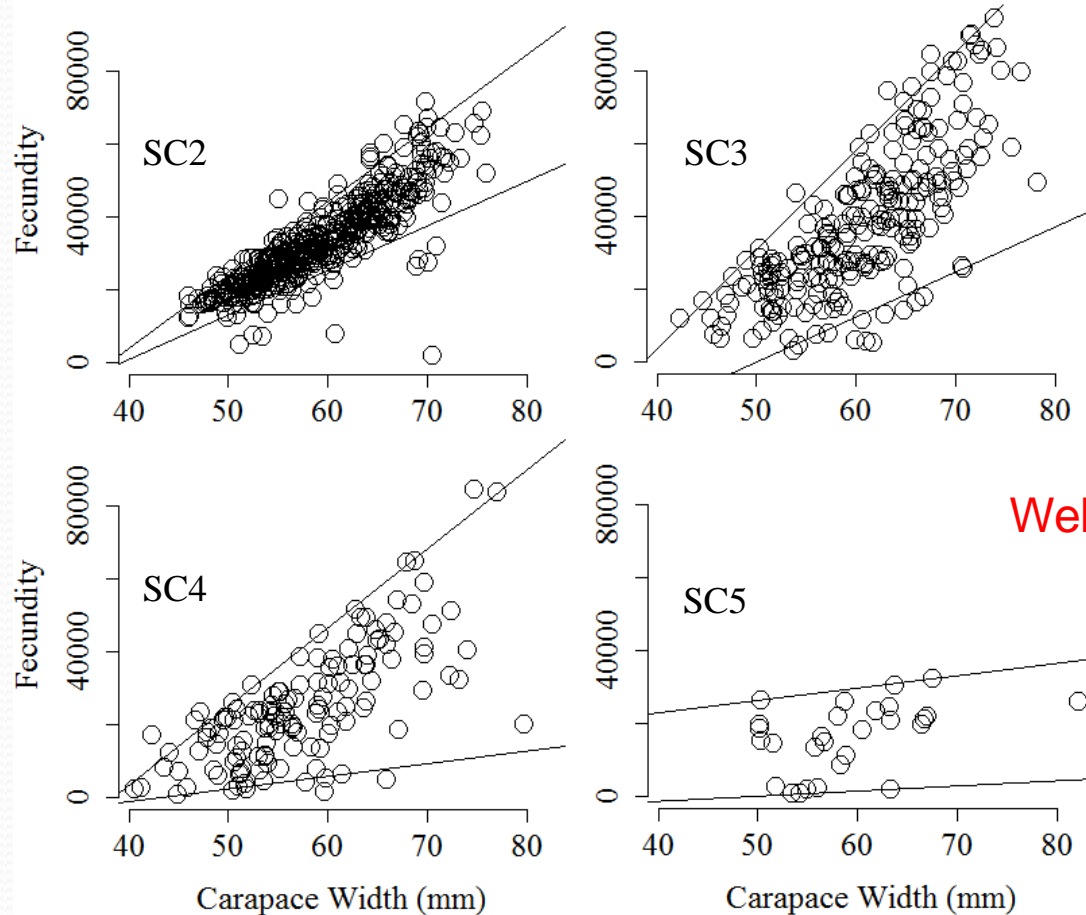
Slater et al. (in prep.)

Estimates of Fecundity at Early Embryo Stage (Summer)



Fecundity by Shell Condition

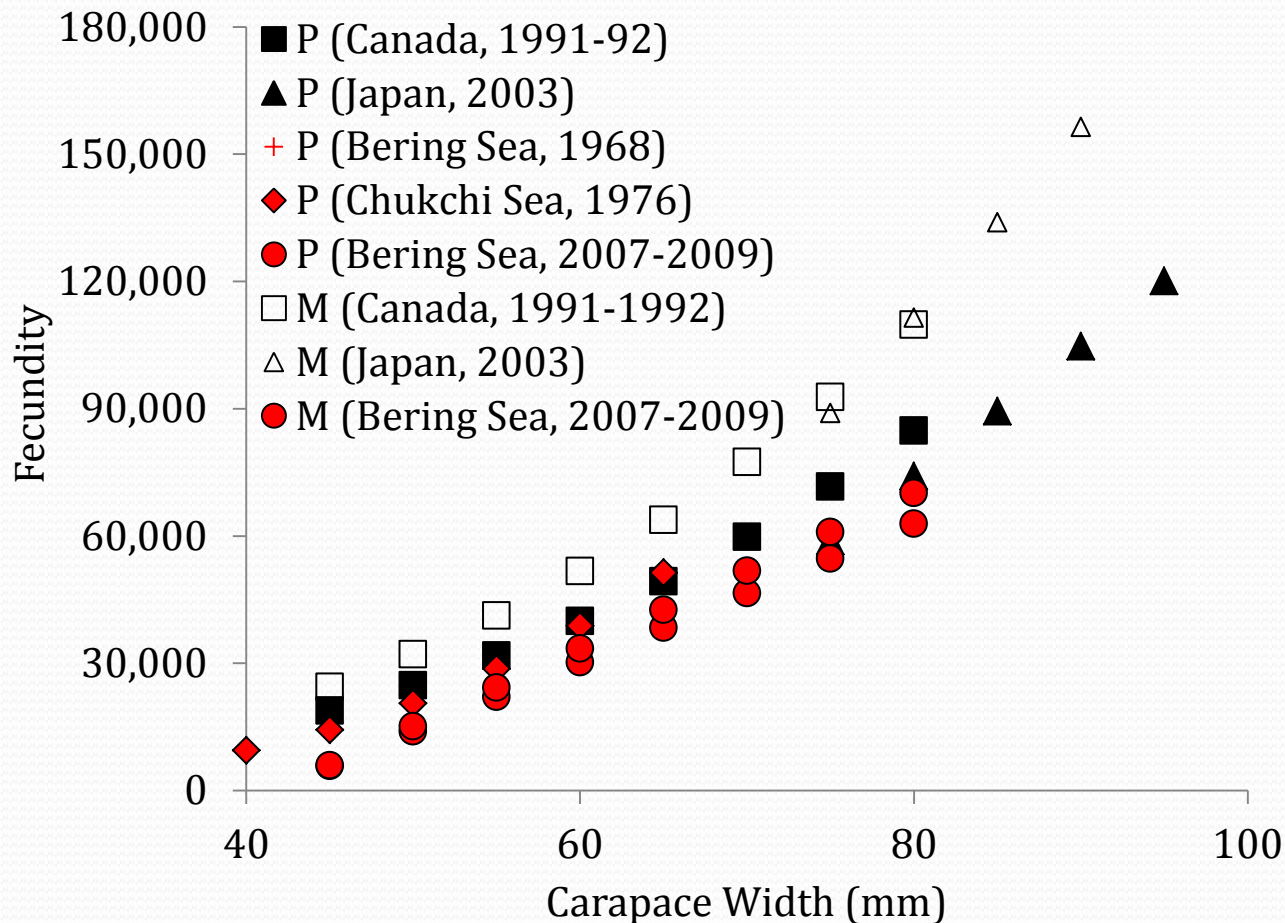
Quantile regression proxies of maximum (95%) and minimum (5%) fecundity



Lower fecundity and higher variability with increasing shell condition (**senescence**)

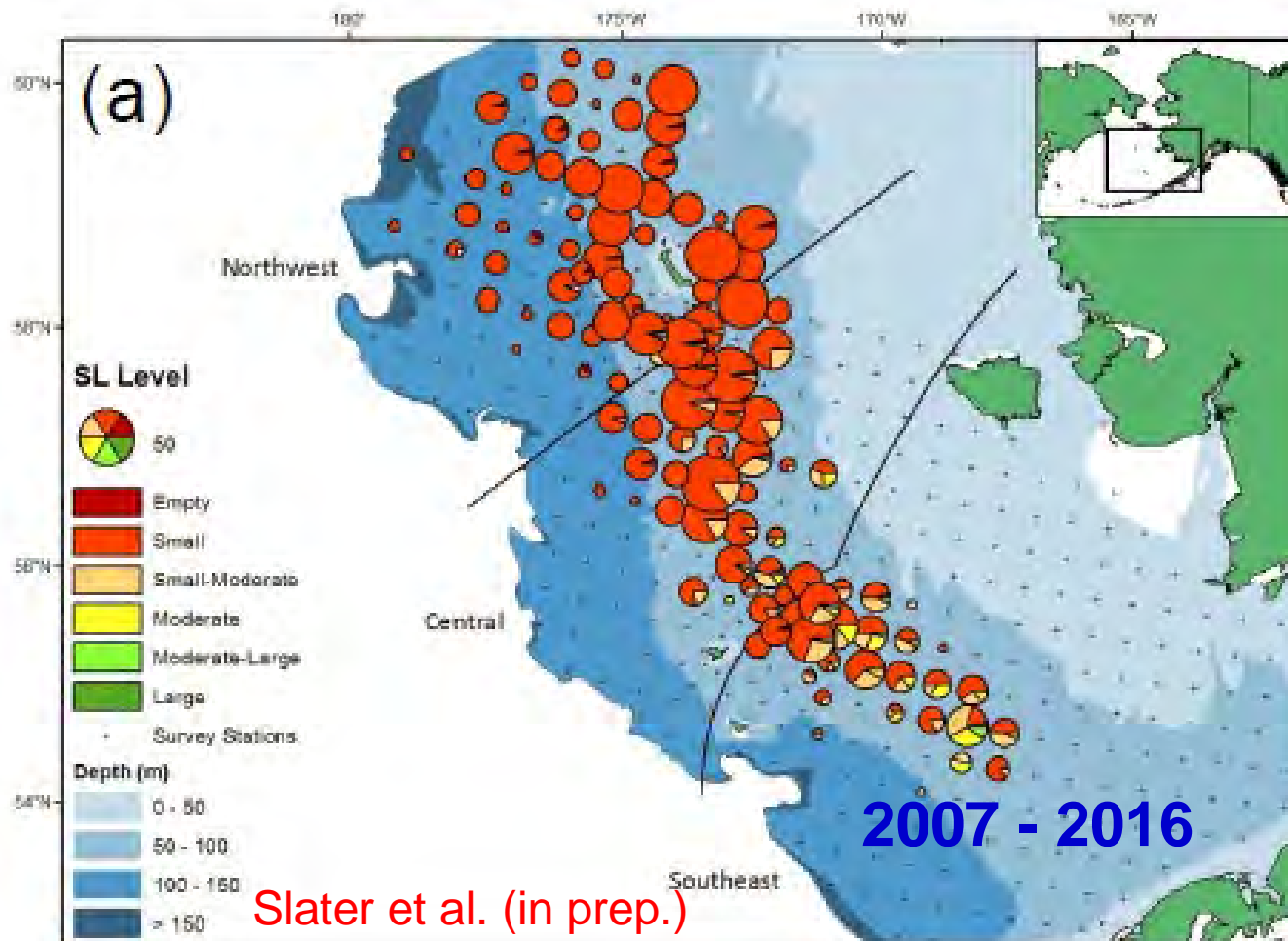
Relatively Low Fecundity of Bering Sea Snow Crab

Webb et al. (2016)



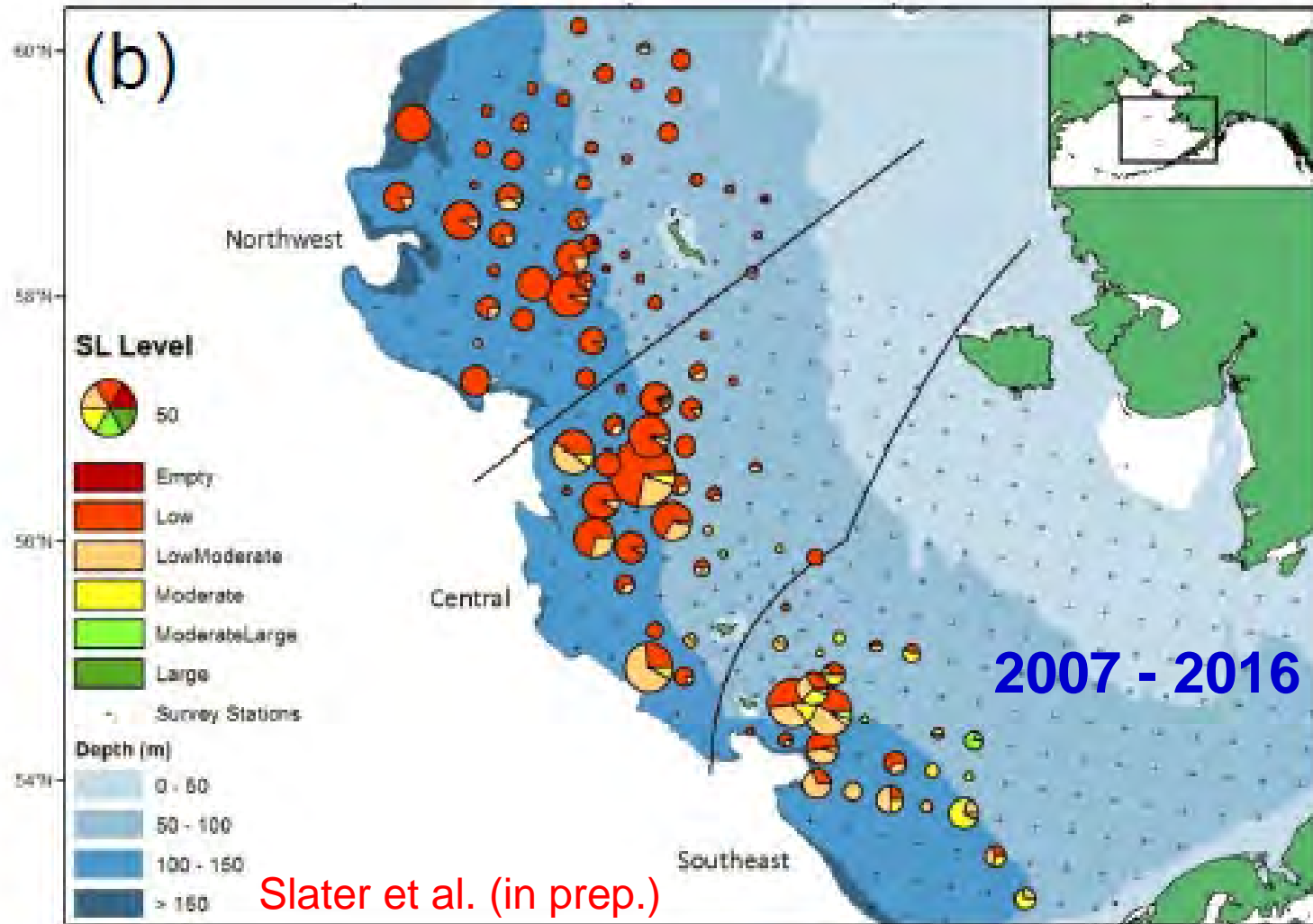
Spermathecal Loads: Primipara

- Sperm may be stored up to 3 years
- Primipara have low SLs especially to north

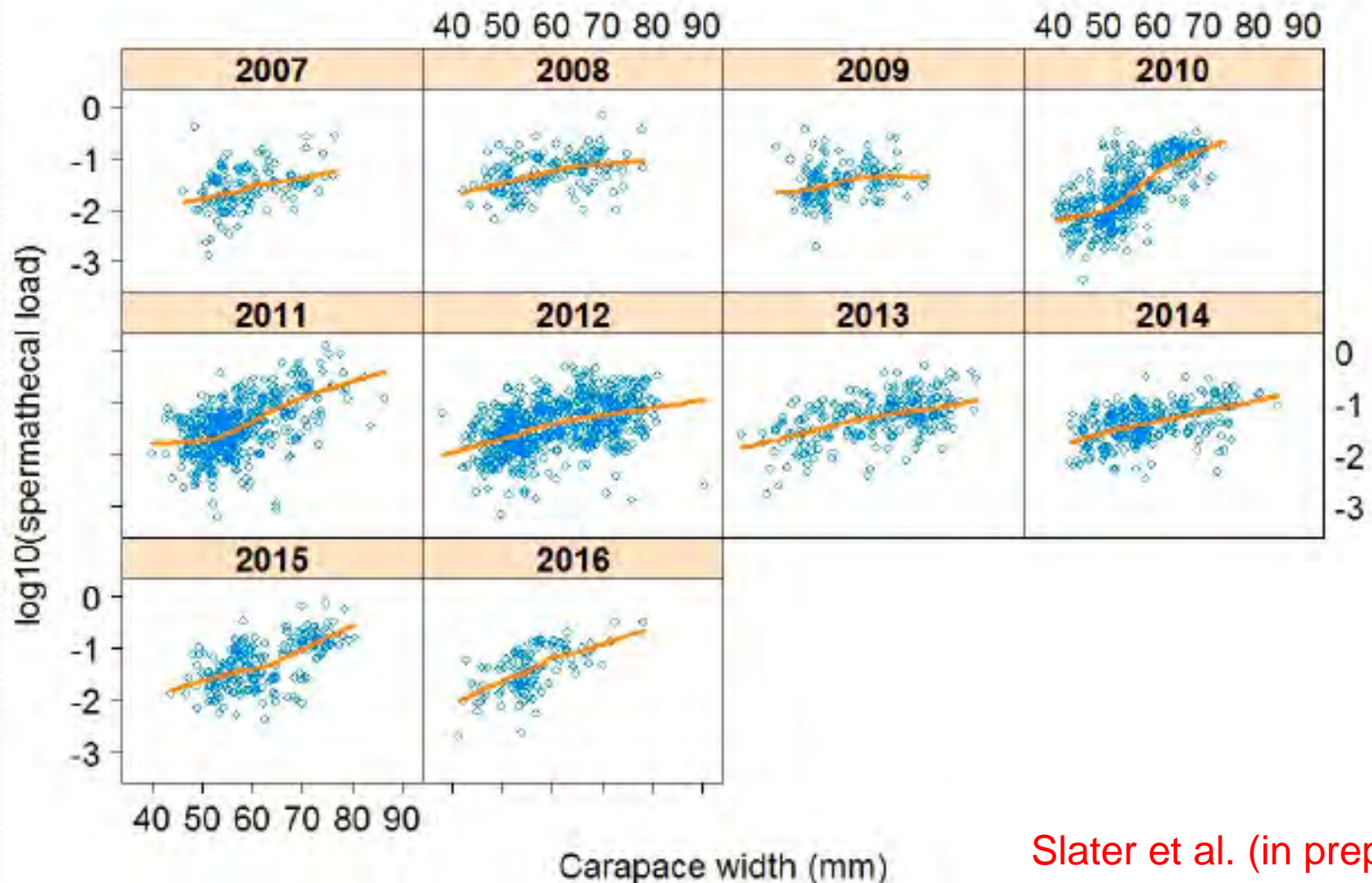


Spermathecal Loads: Multipara

- Similar geographic patterns

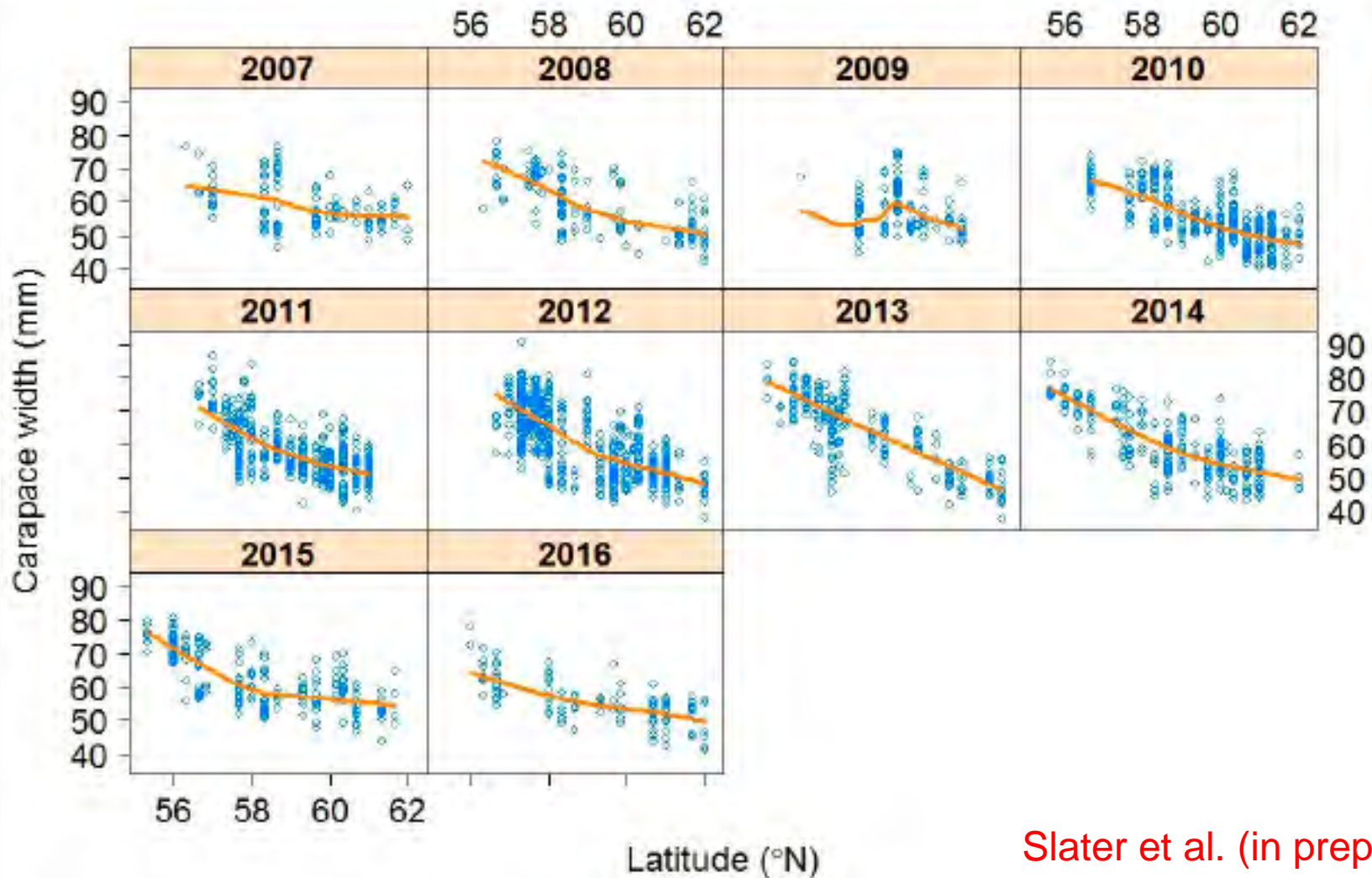


Smaller Females have Smaller SLs



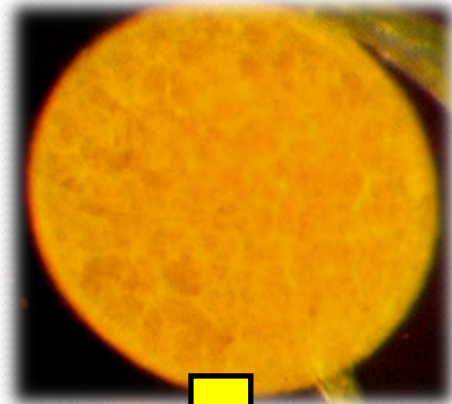
Slater et al. (in prep.)

Female Size Declines with Latitude

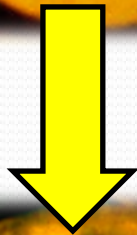


Slater et al. (in prep.)

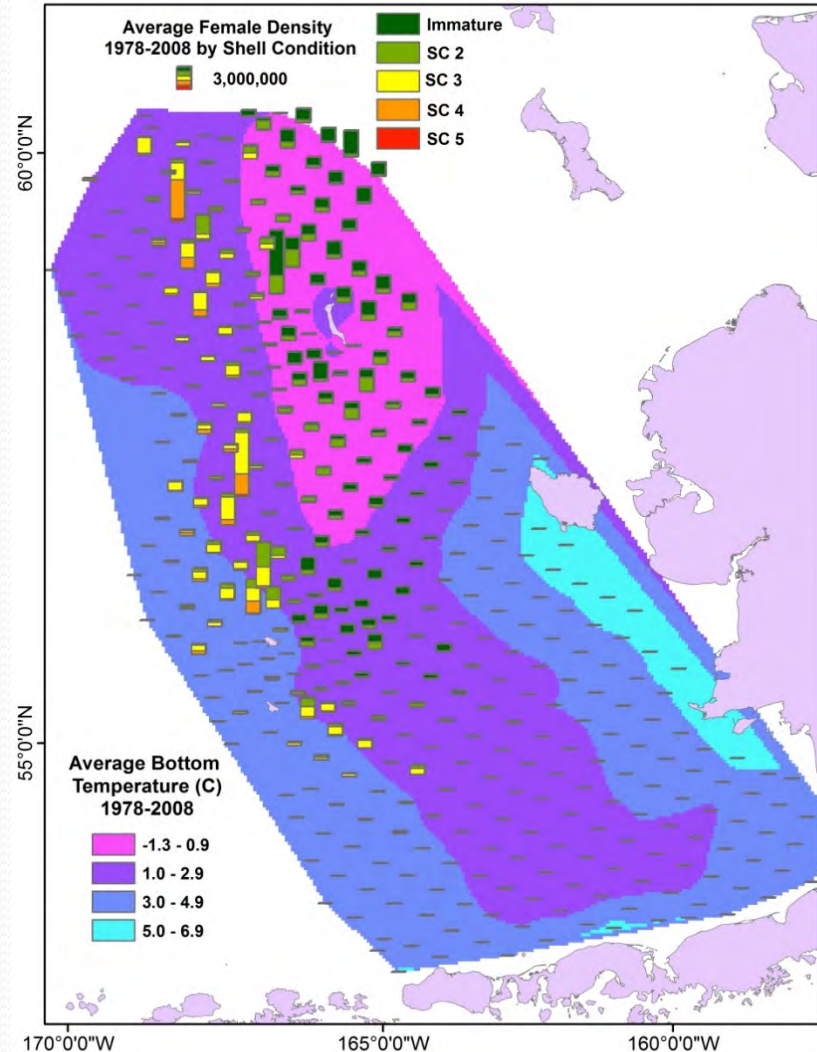
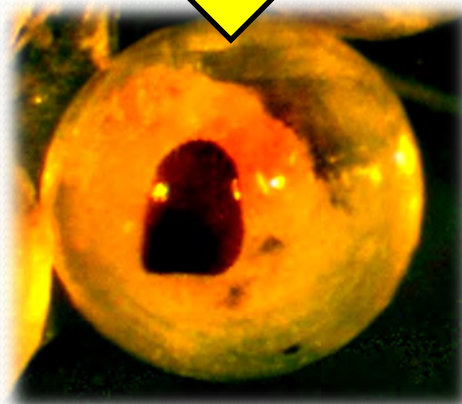
Reproductive Tempo: Annual vs. Biennial



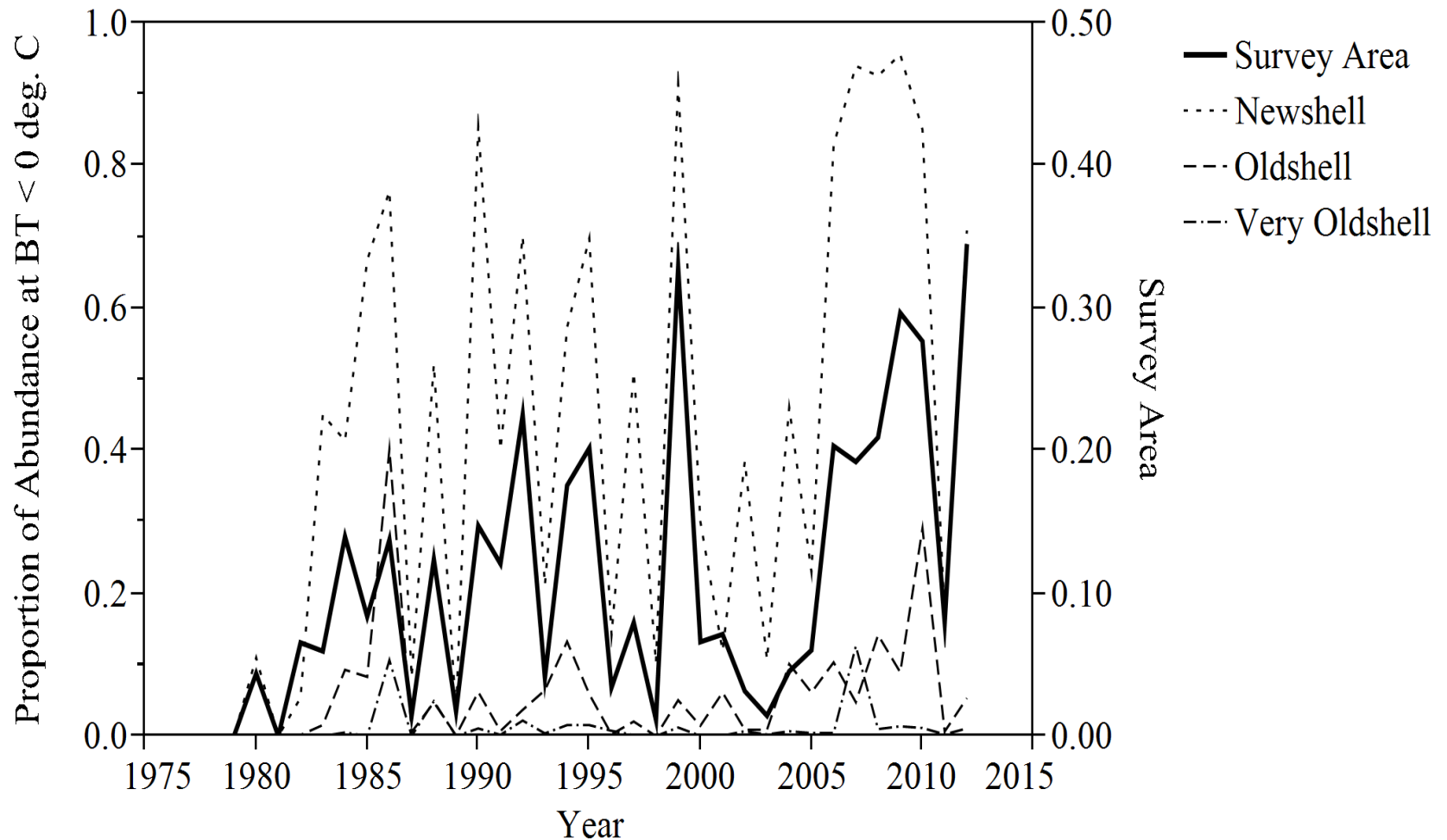
Annual >
1° C



Biennial <1° C

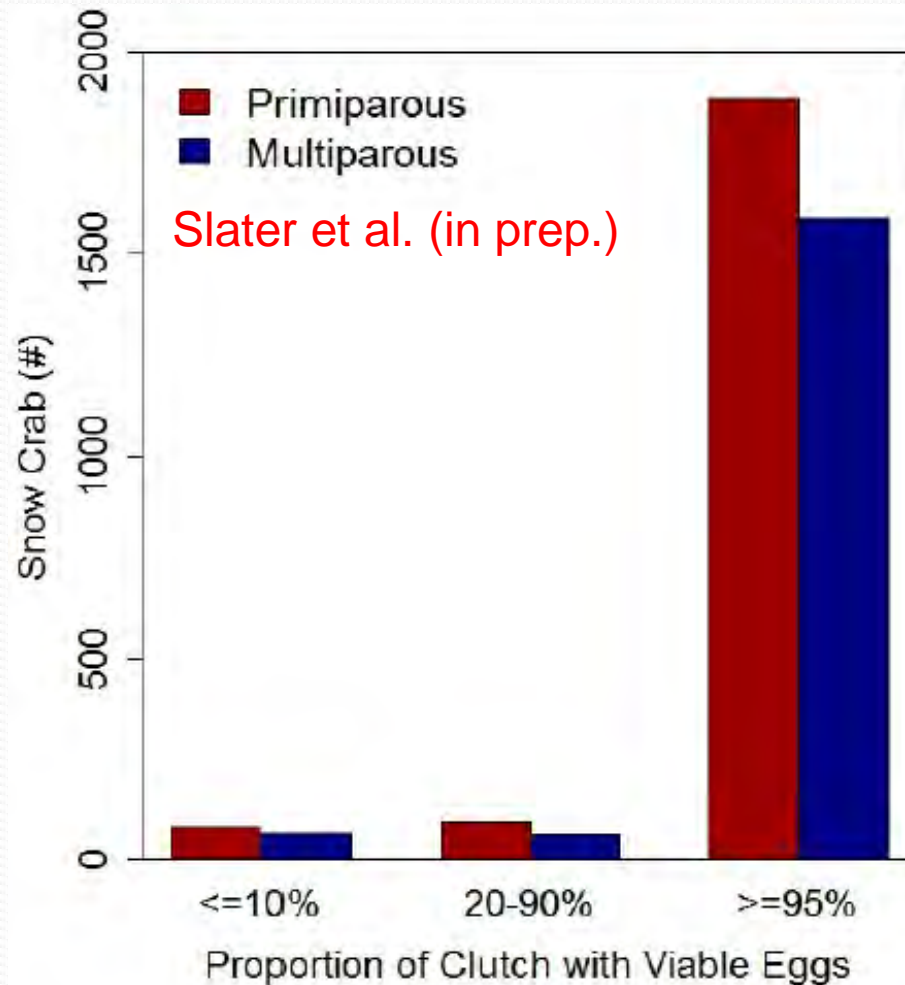


Cold Pool Mainly Affects Newshell Females Owing to Ontogenetic Migration



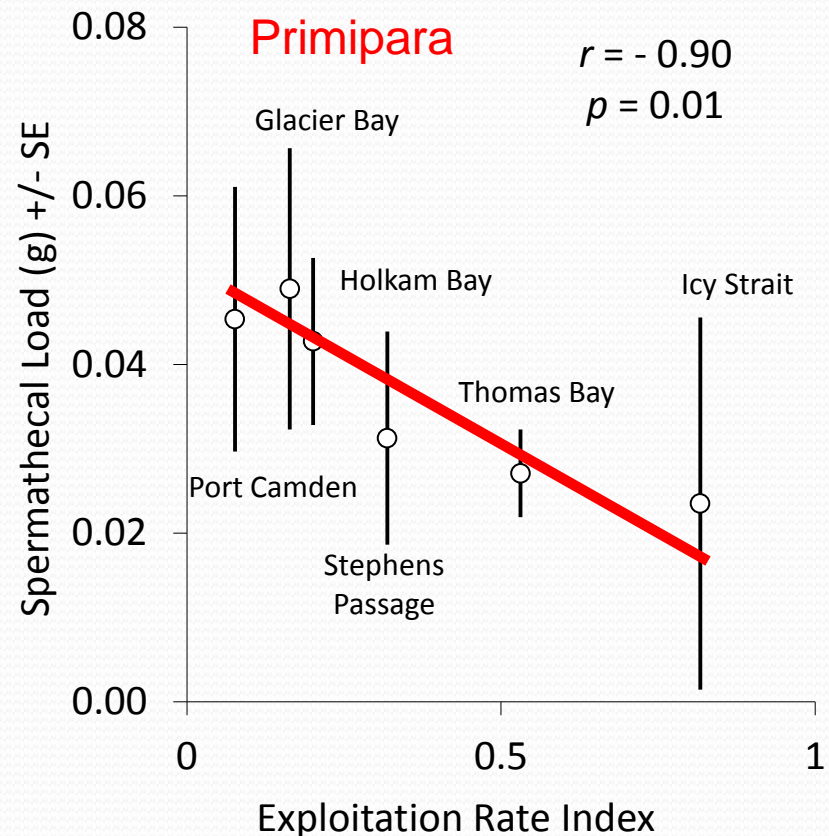
Yet, Most (92%) Females Have Clutches with Mostly Viable Eggs

- No evidence of sperm limitation
- However, remating is necessary
- There is little buffer against future sperm limitation



Caution: Effects of High Exploitation Rate on Tanner Crab in SE Alaska

- Spermathecal loads of primipara declined with harvest rate across 6 stocks
- Spermathecal loads of multipara were directly related to M:F sex ratio (not shown)



Webb & Bednarski (2010)

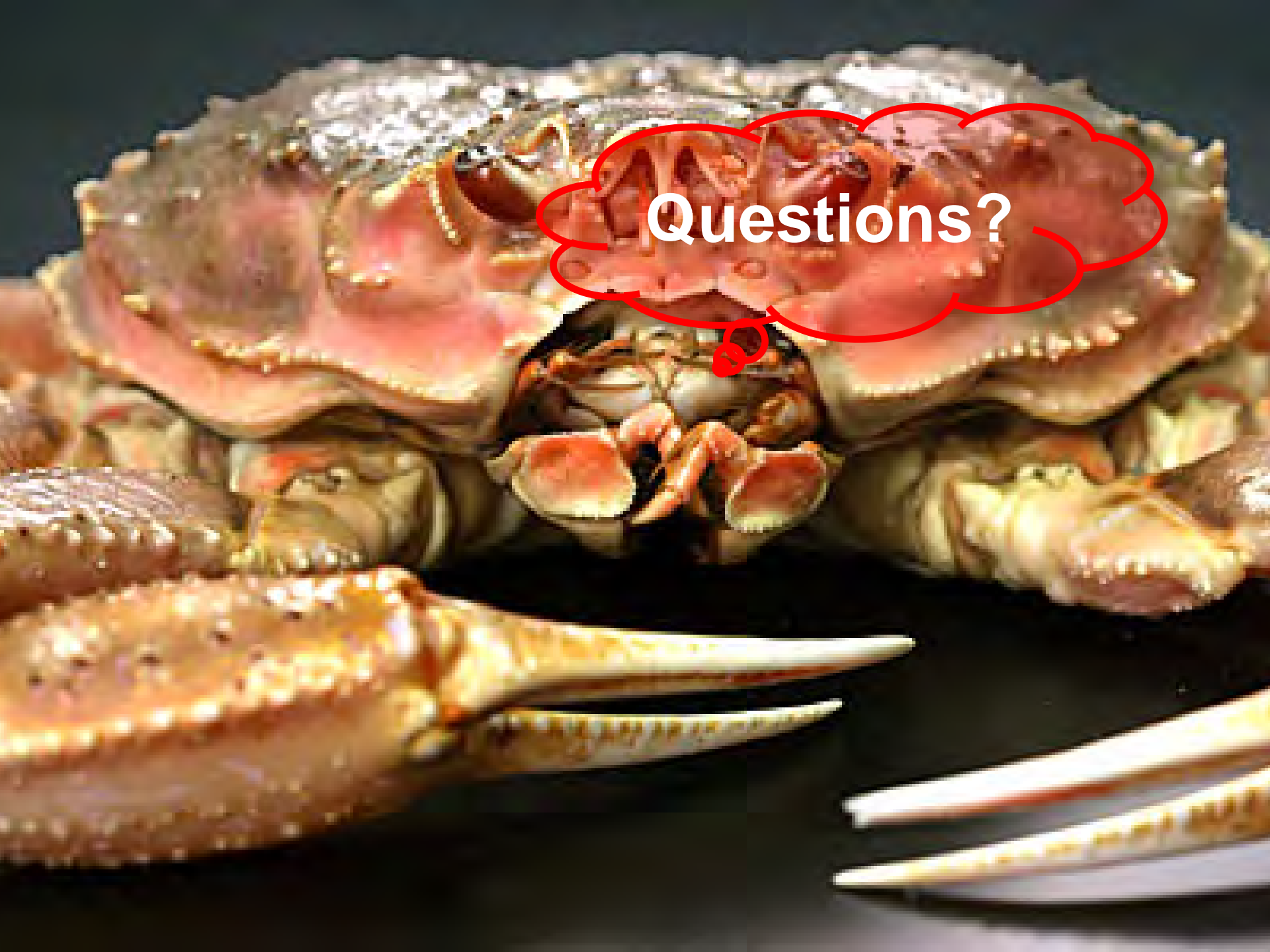
Concluding Thoughts

- Roles of climate, oceanography, predation, and population dynamics on snow and Tanner crab
- Reproductive challenges to snow and Tanner crabs in eastern Bering Sea
- Bering Sea snow crab have low spermathecal loads and low fecundity, in part due to:
 - Ontogenetic migration and limited mating opportunities
 - Asynchronous maturation among males and females
 - Older females become senescent
 - Contraction to north, where body size is smaller
 - Small crab have lower sperm loads and fecundity
 - Females in north more likely to have biennial tempo

Current Research



- Explore relationships between operational sex ratios, sperm reserves, and fecundity
- Snow crab mating dynamics using genetics
 - Genotypes of male mates, paternity of embryos, hybridization between species
- Evaluation of calcified gastric mill ossicles as potential age structures for snow crab
- Better understanding of growth, age of maturity, and natural mortality
 - Improved biological reference points
 - Improved management & fishery outcomes



Questions?