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

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Figure 51. — Total density (number nmi⁻²) of Tanner crab (*Chionoecetes bairdi*) at each station sampled in 2017.

Lang et al. (2017)
Snow Crab Density in 2017

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

Lang et al. (2017)
Snow-Tanner Hybrid Density in 2017

Figure 78. Total density (number km$^2$) of Chionoecetes 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

![Graph showing the annual harvests of Snow and Tanner crabs from 1965 to 2015. The graph indicates fluctuations in harvest quantities with peaks in 1985 and 1995. The red line represents Tanner Crab, and the blue line represents Snow Crab.]
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

<table>
<thead>
<tr>
<th>Shell Condition</th>
<th>Newshell (SC2)</th>
<th>Oldshell (SC3)</th>
<th>Very Oldshell (SC4-5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reproductive status</td>
<td>Immature</td>
<td>Primiparous</td>
<td>Multiparous</td>
</tr>
<tr>
<td>Approximate years post-maturity</td>
<td>$\leq 1$ yr.</td>
<td>$\sim 2-4$ yr.</td>
<td>$4+$ yr.</td>
</tr>
</tbody>
</table>
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)

Shift of males to NW
Orensanz et al. (2004)

Late 70s & Early 80s
Late 90s & Early 00s
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

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

Black = retention (full period)
Red = retention (1978 – 1990)

Richar et al. (2015)
Snow Crab Population Cycles

- Recruitment with periodicity of ~7 yr (~ 1T)
- **Cohort resonance** – greater sensitivity of populations to environmental variability on time scales near one generation time; variability increases with fishing.
• Recruitment residuals of period 13-14 yr (~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)

Webb et al. (2016)
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

Slater et al. (in prep.)

2007 - 2016
Spermathecal Loads: Multipara

- Similar geographic patterns

Slater et al. (in prep.)
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

Slater et al. (in prep.)
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).

\[ r = -0.90 \]
\[ p = 0.01 \]

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?