THE BIOECONOMICS OF SOFT SHELL CRAB: EVALUATING THE IMPACTS OF CHANGING SEASON LENGTH IN OREGON’S DUNGENESS CRAB FISHERY

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Dungeness crab (*Cancer magister*): most valuable single species fishery in Oregon.

- Not well studied: *no assessments, no prior bioeconomic models, fleet behavior not well described*

**Current management:** “3S” (size, sex, season)
- Only crab >159mm carapace width retained
- Only male crab retained
- Traditional season dates are December 1\(^{\text{st}}\)- August 14\(^{\text{th}}\).
- **Summer trip limits**
- **Pot limits** by tier- 200 pots, 300 pots, 500 pots

*Season dates implemented to protect soft shell crab.*
MATING: MALE/FEMALE EMBRACE ➔ MALE MOULTING (SOFT SHELL)

Photo: Scott Groth
Concern: **Impacts of late season fishing:**

- Lots of soft shell crab around (moult is late spring-summer) - not retained
- Higher handling mortality rate for soft shell crab (estimates vary ~ 9%)

**QUESTION:** What are the potential economic impacts of closing the season early?

- Reduce handling mortality $\rightarrow$ more crab next season $\rightarrow$ more benefits
  - **but** -
- Foregone benefits from late season fishing, and who is impacted?

**WHAT CAN WE LEARN?**
**BIOLOGICAL COMPONENT:** 3 cohorts, weekly time step.

1. **LS** - soft shell crab of legal size
2. **LH** - legal size hard shell crab
3. **SL** - sub-legal crab that will moult into the LS cohort *in the next season*.

Younger males, females, not modeled explicitly

**INCLUDE:**

- Moulting/hardening
- Natural mortality
- Fishing mortality (includes handling mortality rates by cohort)
- ‘Recruitment’ is exogenous input of **SL** crab before each season (the ‘gift’)

**BIOLOGICAL COMPONENT**
FISHING EFFORT: Combine a duration model with a Zero-Inflated Poisson model

How does fishing effort change in response to fishery conditions?

Effort:

1. Fishery participation (ENTRY/EXIT)
2. How much effort given participation?

1) Entry behavior stable:
   • Highest catch rates when season starts
   • Why do vessels exit?
Empirical Duration:

- Define ‘fleets’ using participation in 9 defined fisheries (8 years of data)
- Some vessels always leave early - shrimp sub-fleet
- Others remain - open access vessels
- 4 distinct ‘fleets’
How to relate exit probability to changes in fishery conditions?

Discrete Time Hazard Model (DTHM): each fleet modeled separately

Relate probability of exit to:

• Crab revenue (-)
• Ratio of other fishery revenue to crab revenue (+)
• Fuel price (+)
• Vessel characteristics (larger +)
• Fixed effects: pot tier, season
• Weekly time dummies (increasing probability of exit throughout season)
Given participation, how much effort does each vessel exert?

Zero Inflated Poisson model

Relate number of trips per vessel per week to:

- Crab revenue* (+)
- Ratio of other fishery revenue to crab revenue* (-)
- Vessel characteristics (larger vessels make less trips)
- Weekly time dummies (decreasing number of trips throughout season)
- Fixed effects: season, pot tier

* lagged variable by one week
EFFORT = POTS PER WEEK =

POTS/TRIP (average) \times\ NUMBER\ OF\ TRIPS\ (ZIP) \times\ PARTICIPATION\ (duration)

Define 10 ‘sub-fleets’- based on estimation (incorporate parameters into simulation):
  e.g. \textit{st2}: salmon/tuna vessels with a 200 tier pot limit
  e.g. \textit{cr23}: crab only/L.E. vessels with a 200 or 300 tier pot limit.

POLICY ANALYSIS: Hypothetical season closure dates: Week 21 (\sim\ April 15^{th}) to week 38 (August 14^{th}\ traditional\ closure) in week increments (18 closure dates examined).

• Monte Carlo: 1000 iterations for each closure, random recruitment.
BIOECONOMIC FRAMEWORK

- Sub-Legal (SL)
- Soft Shell (LS)
- Legal Hard (LH)

MOULTING

EFFORT → CATCH

HANDLING MORTALITY

NATURAL MORTALITY

WEEK 1

WEEK 2

WEEK 3

WEEK 51

WEEK 52

‘GIFT’ (stochastic)

BIOMASS (year-1)
**BIOECONOMIC SIMULATION**

**SL:** sub-legal

**LH:** legal, hard shell

**LS:** legal, soft shell

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**Graph:**

- **SL:** Sub-legal cohort biomass over the season.
- **LH:** Legal, hard shell cohort biomass over the season.
- **LS:** Legal, soft shell cohort biomass over the season.

- **Cohort Biomass (lbs):**
  - 8e+07
  - 6e+07
  - 4e+07
  - 2e+07

- **Week of the Season:**
  - 5 to 50
Early season closures $\rightarrow$ average negative effect on total profit.
Profit effects differ by subfleet:
Early exiters- Shrimp (sh3, sh5), Crab/LE (cr23, cr5) benefit (also larger vessels).
Lower recruitment (‘gift’) → higher *relative* benefits to closing early
Higher handling mortality rate of soft shell crab → higher benefits of early closures
MOULT TIMING

Start of Moulting Process

- Week 13
- Week 14
- Week 15
- Week 16
- Week 17 (BASE)
- Week 18
- Week 19
- Week 20
- Week 21

Proportion of LH and SL Cohorts that Moul

Week
Moult Timing Effects:
High handling mortality rate, low recruitment example:

![Graph showing the relationship between moult timing and closure weeks.](image)
MAIN RESULTS:
• Early season closures $\rightarrow$ higher starting biomass of harvestable crab
• Higher harvestable biomass $\rightarrow$ higher catch
• However, higher catches $\neq$ higher total profits.
• Foregone profits from after season closure $>\,$ increase in profits due to higher stock and catch.
• Higher handling mortality rates $\rightarrow$ early closures more attractive.
• Early moults $\rightarrow$ early season closures more attractive.
DISTRIBUTIONAL IMPACTS

- Larger vessels benefit (higher pot limits, earlier exit).
- Smaller vessels lose out (lower pot limits, summer fishing)
• Our Bioeconomic Simulation Model provides a tool for learning about interactions between crab life history characteristics and fishermen.

→ Drives hypothesis formation for future research
→ Informs fishery management

• Soft shell crab handling mortality: relatively limited effect on fishery profit
  → Most of increase in LH crab due to reduced harvest mortality of LH crab
  → Depends on costs

• Model calibration highly dependent on natural mortality rates.

Need further research: price effects, moultling process, stock dynamics
QUESTIONS?