Adaptation to climate variation in a diversified fishery: The West Coast groundfish trawl fishery

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The West Coast groundfish trawl fishery

• 26% of all fish (including shellfish) landed on the West Coast of the United States

“Two” fisheries

“Non-whiting”: over 30 groundfish species and rockfish complexes

“Whiting”: Pacific whiting

• Only about 50% of their annual revenue comes from the groundfish fishery

Dungeness crab
Pink shrimp

Alaska pollock
The West Coast groundfish trawl fishery

- Non-whiting groundfish species are generally long-lived, spatially stable
  - Little research and no direct links to climate factors
- Whiting are short-lived, high abundance and highly variable abundance, and migrate from south to north each year
  - Climate does not directly affect fish production, but does impact distribution (Agostini et al. 2006)

- Dungeness crab, shrimp, and Alaska pollock are greatly affected by climate factors, in different ways
The California Current

- **Winter conditions:**
  - Northward shelf currents, winds from the south, coastal downwelling

- **Summer conditions:**
  - Strong southward surface currents, weak bottom currents, coastal upwelling

- “Spring transition” is reflected in coastal sea level measurements, which fall rapidly in the spring
Dungeness crab

- Northern California, Oregon and Washington
- Fished with pots
- Fishing removes essentially all 4-year old male crabs
- No fishing mortality-stock-recruitment relationship
Dungeness crab & the California Current

- Adult population size is determined by success at larval stage
- Early spring transitions are correlated with larval success, and larger adult populations 4 years later
- Season opening based on quantity and shell hardness

Relationship between date of spring transition and t+4 commercial catches
Shanks and Roegner, 2007
Pink (ocean) shrimp

- Northern California, Oregon and Washington
- Fished with trawl gear
- Lifespan of 3 years; fished at ages 1 and 2
- No fishing mortality-stock-recruitment relationship
Pink shrimp and the California Current

- Low sea levels in April ("strong"/early spring transition) correlated with increased recruitment

- Hypothesized that late spring transitions would transport larvae northward and onshore, where poor survival expected

Relationship between April sea level height and recruits
Hannah, 1993 and 2011
How do participants respond to these effects? Hypotheses:

• Large fishable biomass of crab and shrimp (early spring transition in t-4 and t-2) correlated with
  • lower participation and
  • lower % of revenue (for participants) from groundfish.

• Response constrained by the trip-limit regulations in the groundfish fishery until 2011

• Likely to be more responsive under catch share management (2011 forward)
Participation in LE groundfish increases with later spring transition

\[ \beta = 0.04 \]

\[ (t = 2.30) \]
Participation in LE groundfish increases with larger crab and shrimp harvests and later spring transitions

Probability of participation (XT logit)

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Given participation, % of revenue from groundfish increases with later spring transition in t-4

\[ \beta = 0.14 \quad (t = 3.38) \]
% of revenue from groundfish increases with larger crab and shrimp harvests and later spring transitions

<table>
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<th>Std. Error</th>
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N = 1701
Using only vessels that *always* participate in the groundfish trawl fishery, effect is somewhat stronger

\[ \beta = 0.20 \quad (t= 4.69) \]
Using only vessels that *always* participate in the groundfish trawl fishery:

| Variable                  | Estimate | Std. Error | t value | Pr(>|t|) |
|---------------------------|----------|------------|---------|---------|
| crab_t_mts                | -0.715***| 0.111      |         |         |
| shrimp_t_mts              | -0.508***| 0.188      |         |         |
| year                      | 0.839*** | 0.532**    | 0.233   |         |
| L4.spring_trans           | 0.199*** | 0.028      | 0.045   |         |
| L2.spring_trans           | 0.045    | 0.032      |         |         |
| _cons                     | -1588.927*** | -1025.354** | 471.078 | 467.209 |

| N                         | 462      | 462        |

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Crab [mts] -0.715*** 0.111
Shrimp [mts] -0.508*** 0.188
Year 0.839*** 0.532** 0.233
L4 Spring 0.199*** 0.028
L2 Spring 0.045 0.032
Cons -1588.927*** -1025.354** 471.078 467.209

N 462 462
California Current climate change predictions

- Increased upwelling in the summer months driven by wind-stress curl driven by the land-ocean temp gradient (Snyder et al 2003)
- Shift of peak upwelling to later in the year (Barth et al 2007)
- El Niño associated with delayed and weak upwelling (Bograd et al 2009)
How do catch shares affect predictions?

- Prior to 2011, the groundfish fishery was managed mainly with monthly trip limits.

- Now, fishermen can “specialize” in groundfish fishing for a limited time of the year.
Specialization
How do catch shares affect predictions?

• Catch shares are often considered to increase flexibility (although among fisheries, it is not clear)

• Expect behavior to be more sensitive to variation in the shrimp and crab fisheries

• More likely to optimally divide time among fisheries as a function of prices and other market conditions
  • Lead to a more “predictable” model of participation and effort allocation?
Future steps

• Model days at sea (effort) and profit per day in each fishery
• Participation model that can predict diversification and revenue/profits depending on climate and TAC conditions
• Whiting/pollock
• Predictability (?) of crab season opening may change the way vessels deal with groundfish quota at the end of the calendar year
• Ocean acidification?
Alaska (Walleye) pollock

- Bering Sea and Aleutian Islands of Alaska
- Fished with trawl gear by vessels that target whiting on the West Coast
- Pollock roe (from pre-spawning fish) is harvested in the winter (Jan-Mar) season
Pollock and Bering Sea temperature regimes

- Bering Sea is characterized by warm and cold temperature regimes
- Peak of egg stage occurs 40 days earlier in warm years
- Harvesters start fishing earlier to obtain peak value roe

Comparison of egg stage in cold and warm regimes
Smart et al, 2012

Timing of spring fishing trips
Haynie and Pfeiffer, 2013