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

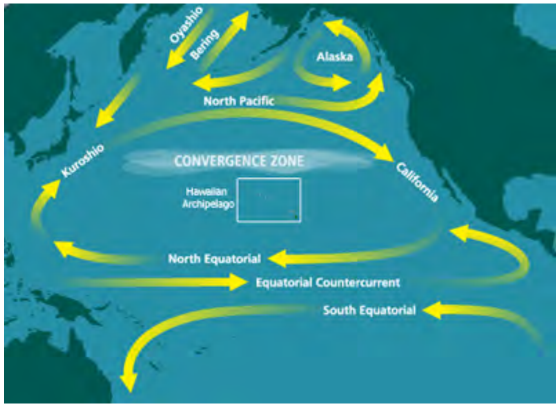
Dungeness crab
Pink shrimp

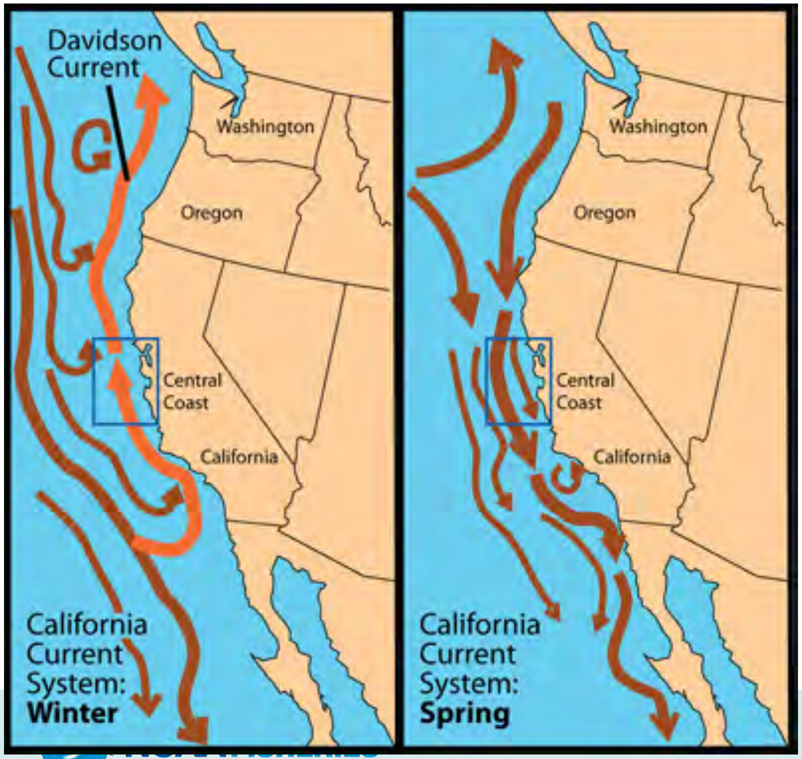
Alaska pollock

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



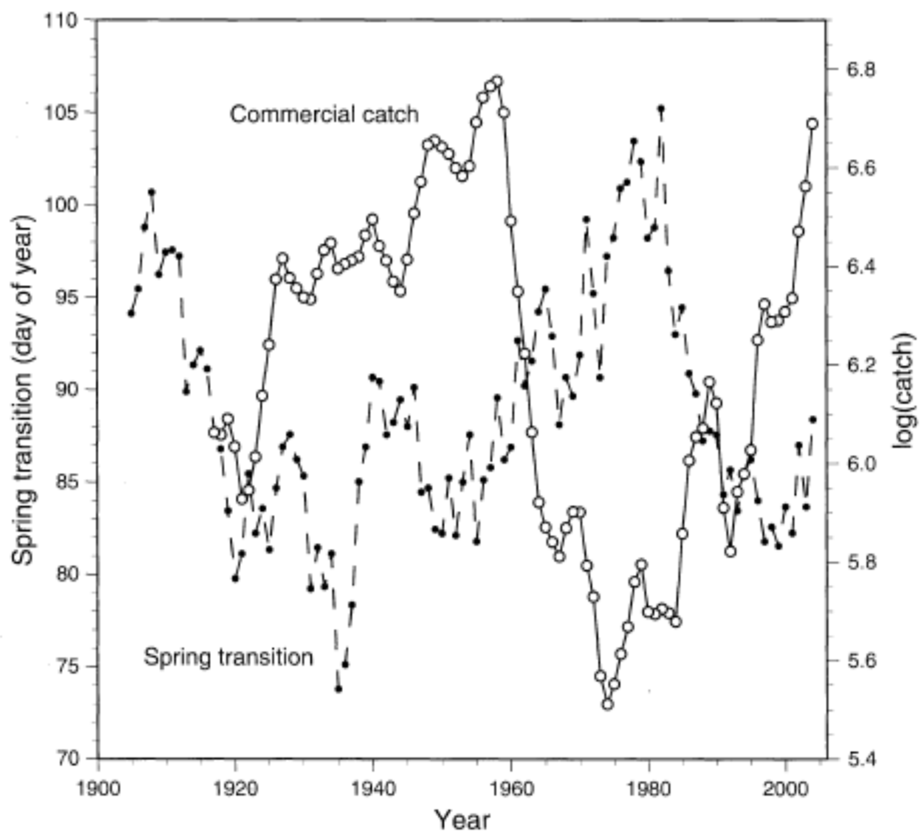


- Winter conditions:
  - Northward shelf currents, winds from the south, coastal downwelling
- Summer conditions:
  - Strong southward surface currents, weak bottom currents, coastal upwelling
- "Spring transition" is reflected in coastal sea level measurements, which fall rapidly in the spring

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



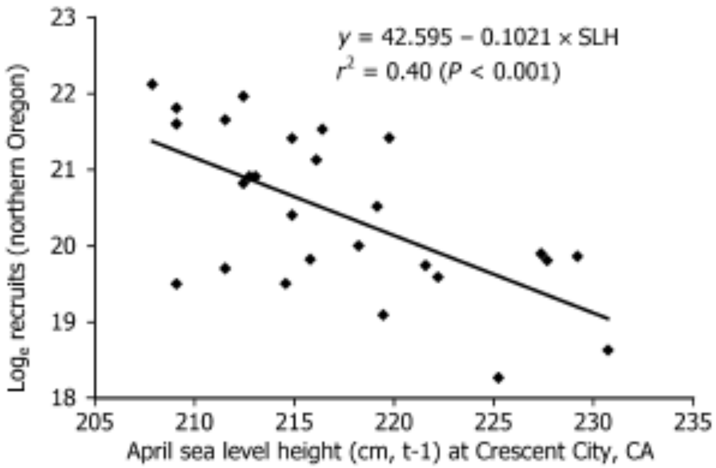
Relationship between date of spring transition and t+4 commercial catches
Shanks and Roegner, 2007

- 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

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



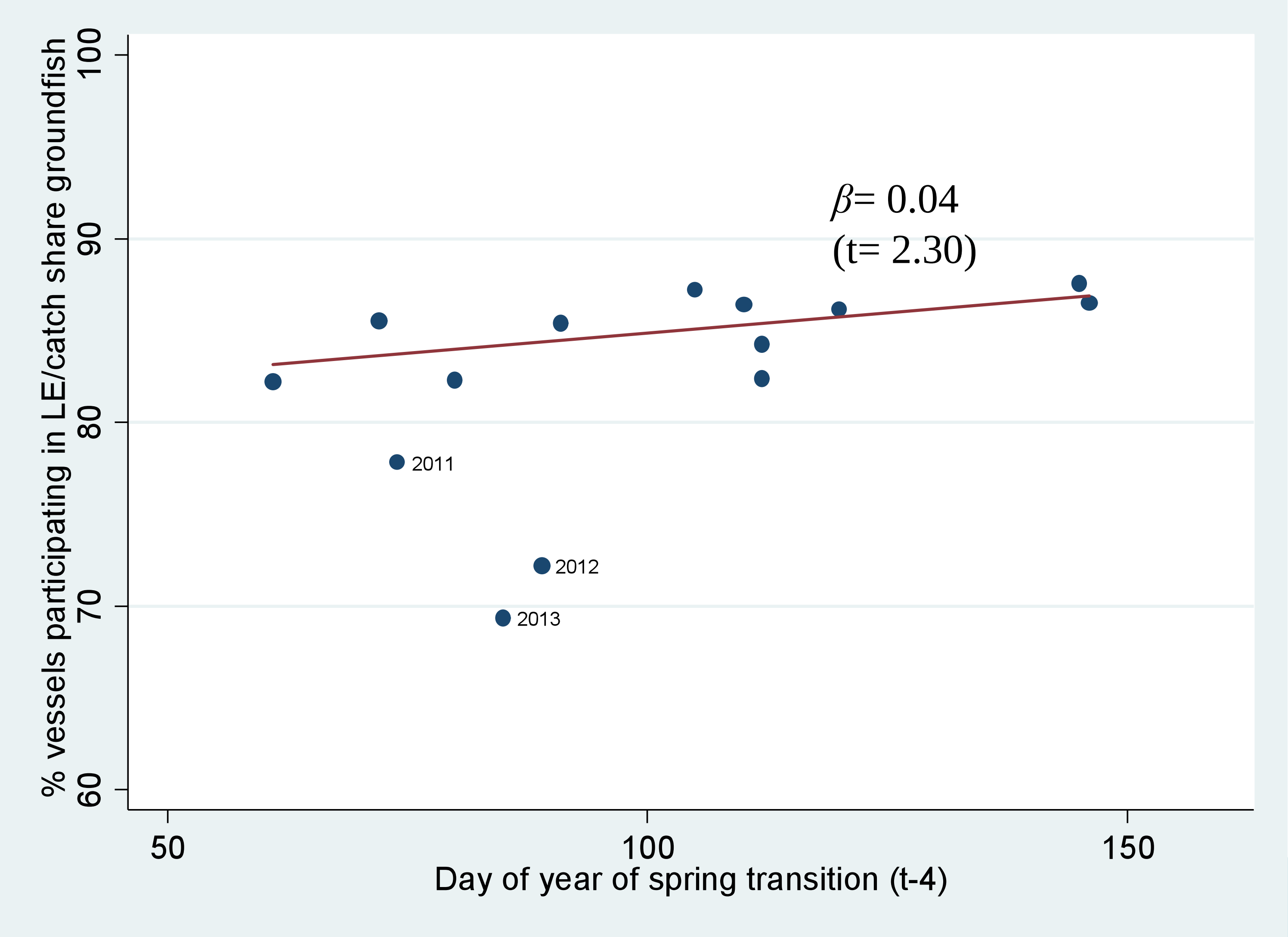
Relationship between April sea level height and recruits
Hannah, 1993 and 2011

- 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

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

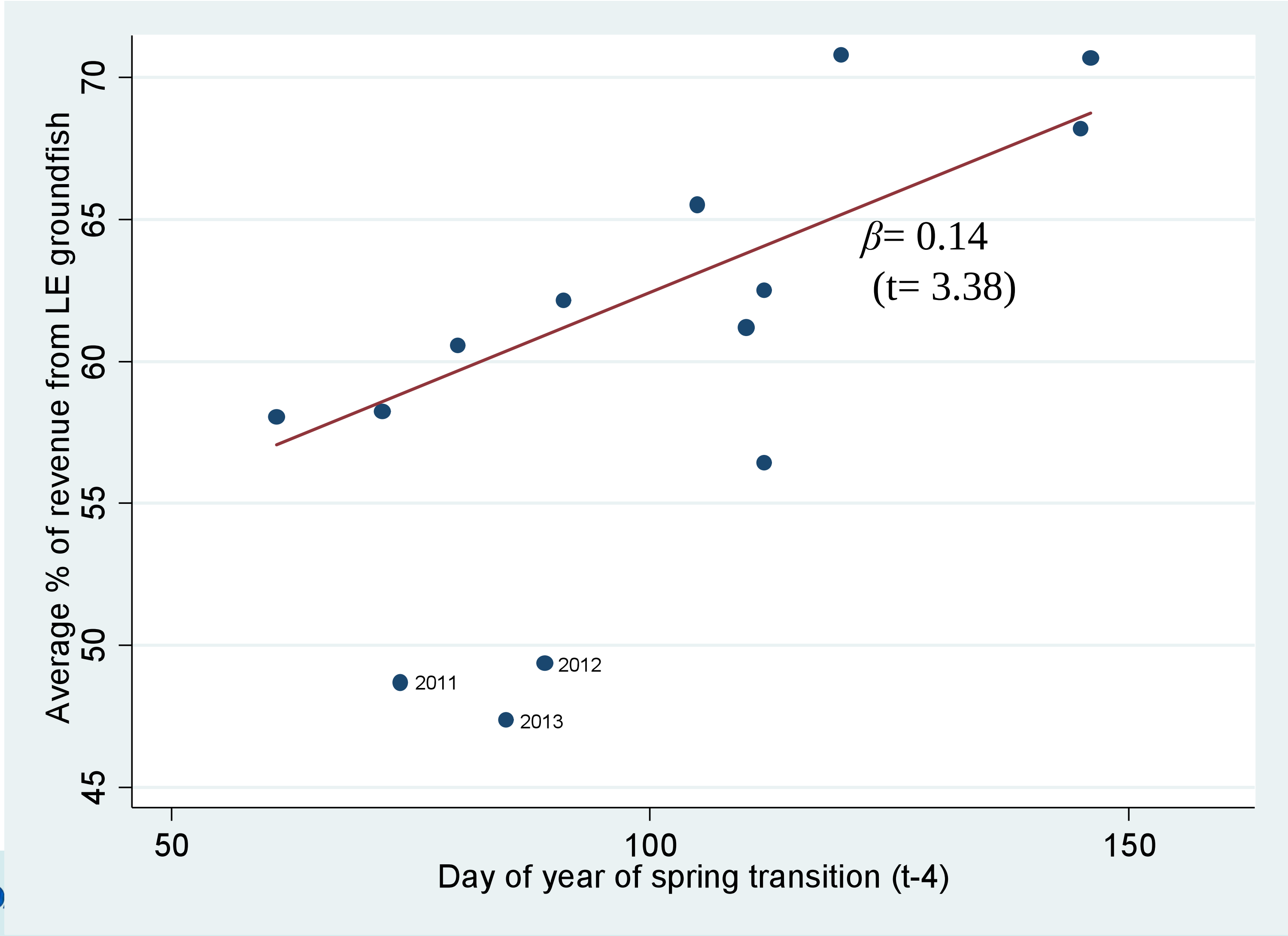


Participation in LE groundfish increases with larger crab and shrimp harvests and later spring transitions

Probability of participation (XT logit)

gfv		
crab_t_mts	-0.051***	
	0.020	
shrimp_t_mts	-0.028	
	0.039	
price_gf	2.164	1.418
	3.963	3.639
L4.spring_trans		0.012**
		0.005
L2.spring_trans		0.003
		0.007
_cons	7.990***	5.083***
	2.702	1.694
lnsig2u		
_cons	3.890***	3.870***
	0.167	0.167
N	1994	1994

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

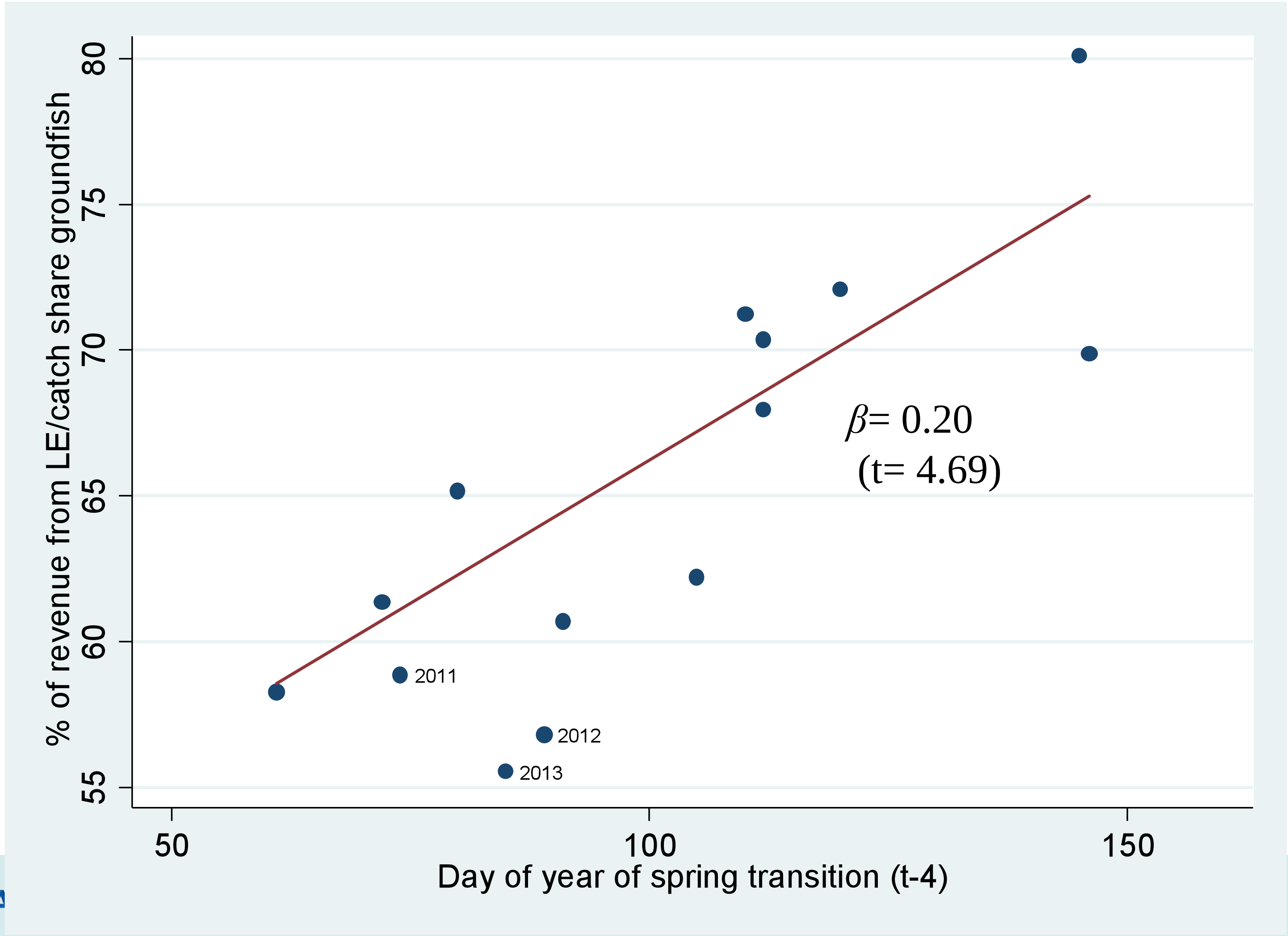


NO

% of revenue from groundfish increases with larger crab and shrimp harvests and later spring transitions

crab_t_mts	-0.608***	
	0.073	
shrimp_t_mts	-0.613***	
	0.118	
year	0.275	0.102
	0.173	0.172
L4.spring_trans		0.138***
		0.018
L2.spring_trans		0.071***
		0.021
_cons	-461.870	-162.467
	347.653	343.731
N	1701	1701

Using only vessels that ***always*** participate in the groundfish trawl fishery, effect is somewhat stronger



NOAA

Using only vessels that ***always*** participate in the groundfish trawl fishery:

	(1)	(2)
crab_t_mts	-0.715***	
	0.111	
shrimp_t_mts	-0.508***	
	0.188	
year	0.839***	0.532**
	0.235	0.233
L4.spring_trans		0.199***
		0.028
L2.spring_trans		0.045
		0.032
_cons	-1588.927***	-1025.354**
	471.078	467.209
N	462	462

California Current climate change predictions

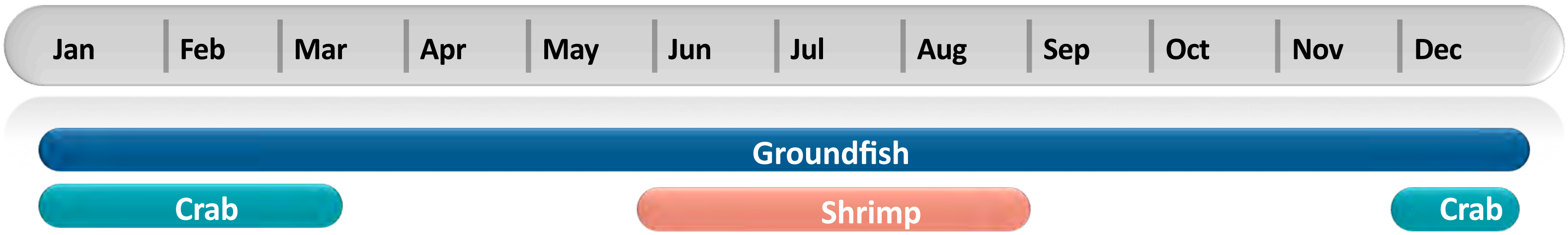
- Increased upwelling in the summer months driven by wind-stress curl driven by the land-ocean temp gradient (Snyder et al 2003)
- Shift of peak upwelling to later in the year (Barth et al 2007)

  → Later spring transition

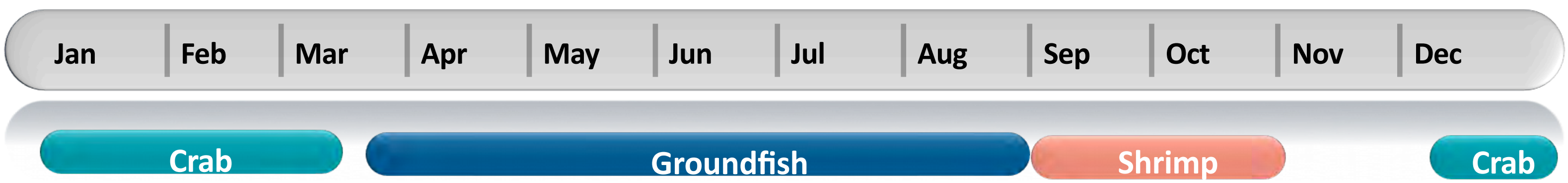
- El Niño associated with delayed and weak upwelling (Bograd et al 2009)

How do catch shares affect predictions?

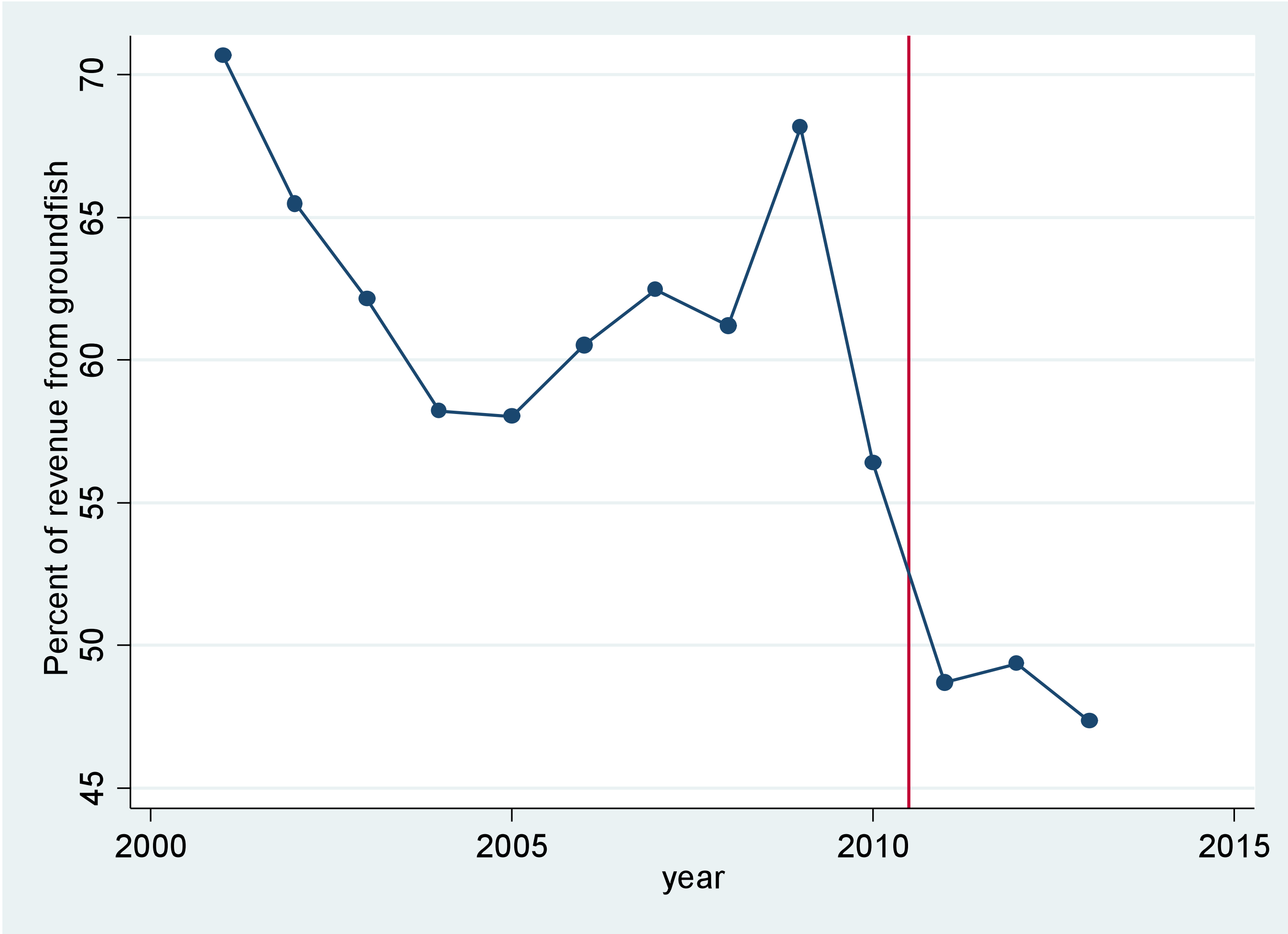
- Prior to 2011, the groundfish fishery was managed mainly with monthly trip limits



- 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

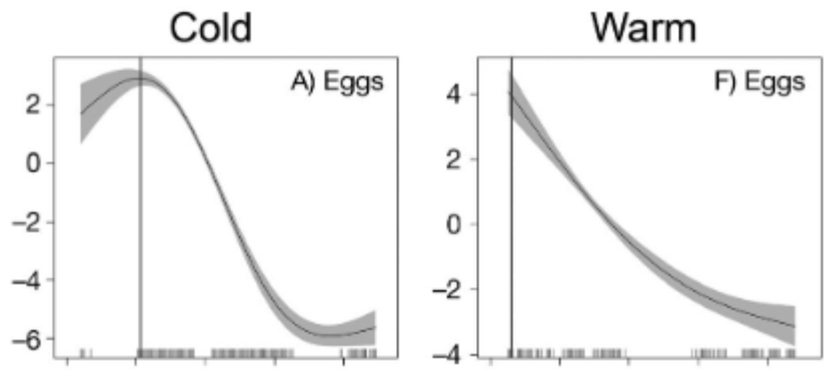
- Model days at sea (effort) and profit per day in each fishery
- Participation model that can predict diversification and revenue/profits depending on climate and TAC conditions
- Whiting/pollock
- Predictability (?) of crab season opening may change the way vessels deal with groundfish quota at the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



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

	(1) Probability of an early trip	(2) Probability of an early trip
Lagged summer SST	2.190** (0.69)	
Lagged fall SST		1.147* (0.47)
TAC (vessel-specific, thousand t)	0.348** (0.10)	0.344** (0.10)
Ratio of roe to surimi prices (average of t and t − 1)	−0.175 (0.24)	−0.562** (0.19)
Total abundance (million t of age 3+)	−0.254 (0.19)	−0.234 (0.17)
Ice cover index	−0.050 (0.21)	−0.581** (0.10)
Constant	−17.444** (6.25)	−3.652 (3.14)
Observations	176	176
Pseudo-R^2	0.444	0.415

Timing of spring fishing trips
Haynie and Pfeiffer, 2013

- 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