NOAA FISHERIES

AFSC

Maturity Schedule Information

Anne Hollowed, Steve Barbeaux, Martin Dorn, Robert Foy, Dana Hanselman, Pete Hulson, Sandi Neidetcher, Paul Spencer, Jim Stark and several graduate students

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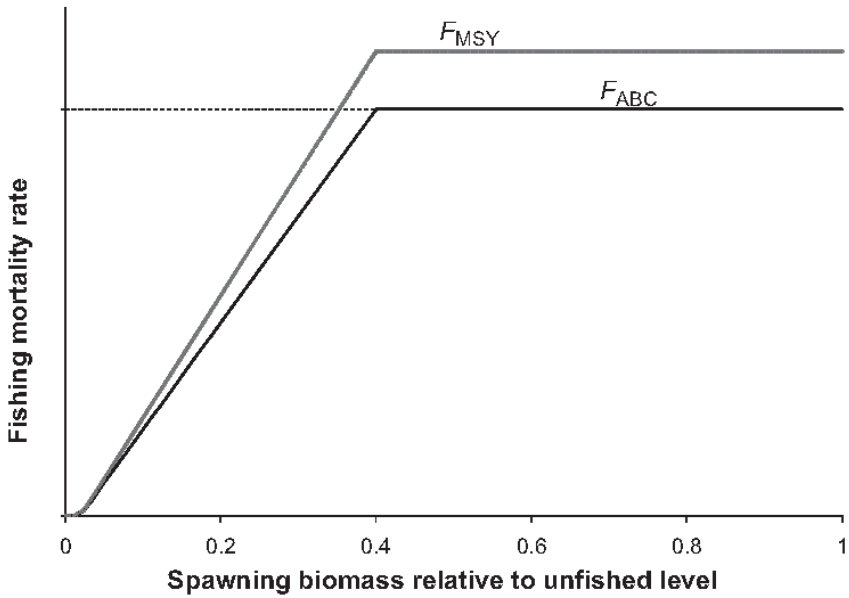
Groundfish Harvest Strategy

Schematic of Harvest Control Rule



- Control rule strives to utilize index of reproductive potential in units of spawning biomass
- Maturity schedule is fundamental to harvest strategies
- Fishing and environmental variability can alter maturity schedules
- Most assessments don't consider interannual variability in maturity schedule
- Peak spawning timing is a critical input to stock assessments.

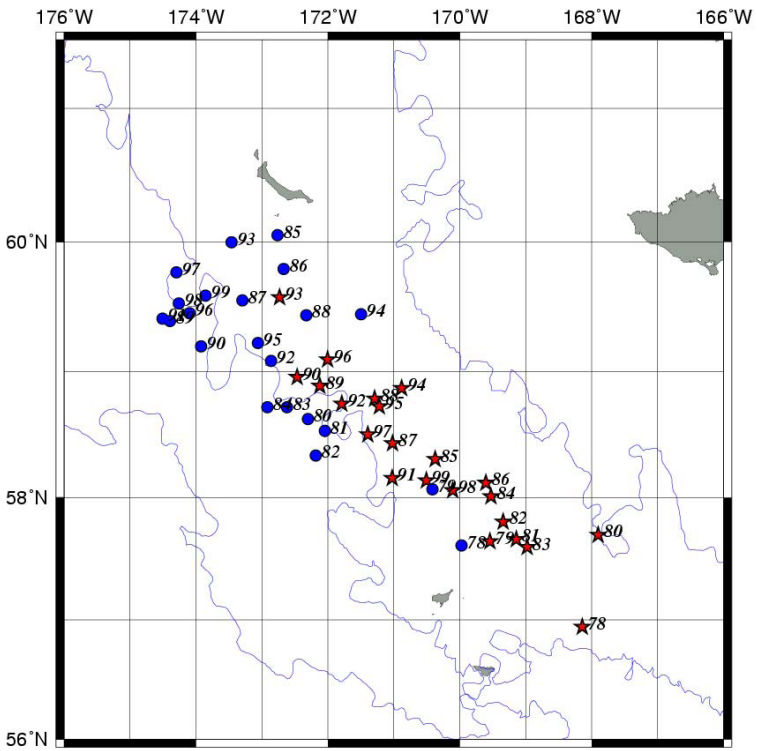
Catch ≤ TAC ≤ ABC/ACL < OFL

Total Allowable Catch | Acceptable Biological Catch | Overfishing Level

Crab Harvest Strategy

To transition to FEP need information on molting probabilities, mating ratios, spatial overlap of males and females by size

- Mature male biomass used as proxy for fertilized egg production (FEP)
- Maturity schedule is fundamental to harvest strategies
- Assessments don't consider interannual variability in maturity schedule
- Peak spawning timing is a critical input to stock assessments.
- Fishing and environmental variability can alter maturity schedules. In some stocks biennial cycles exhibited in cold years.



Centroids of abundance of mature female snow crabs (shell condition 2+, blue) and mature males (shell condition 3+) red stars (Ernst et al. 2005)

Crab Maturity-females

EGG/CLUTCH CONDITIONS:

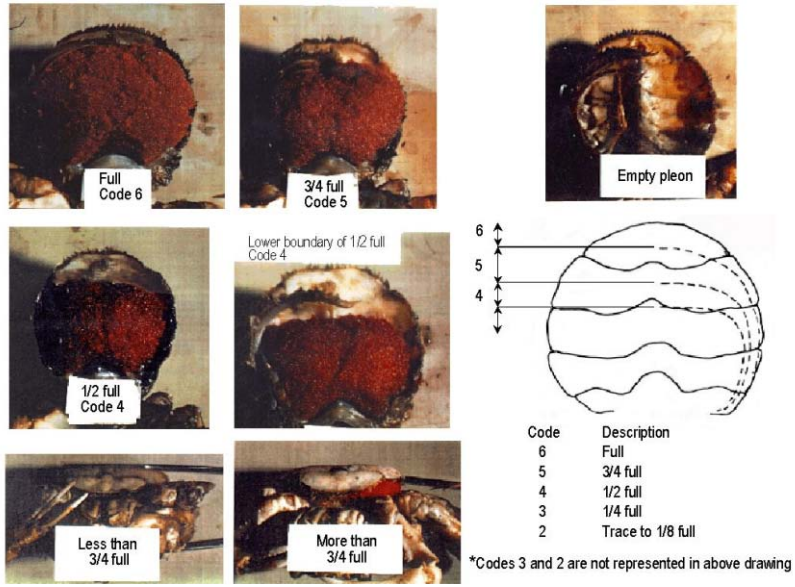
Egg Color Enter egg color code:

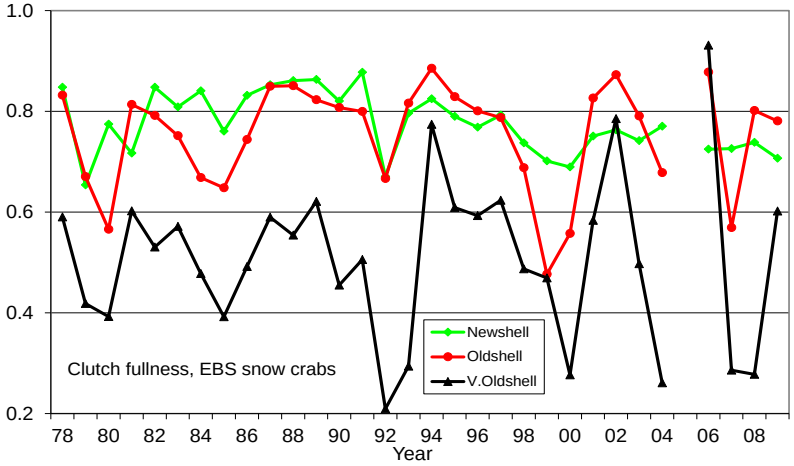
- 0 - No eggs
- 2 - purple
- 3 - brown
- 4 - orange
- 5 - purple-brown
- 6 – pink

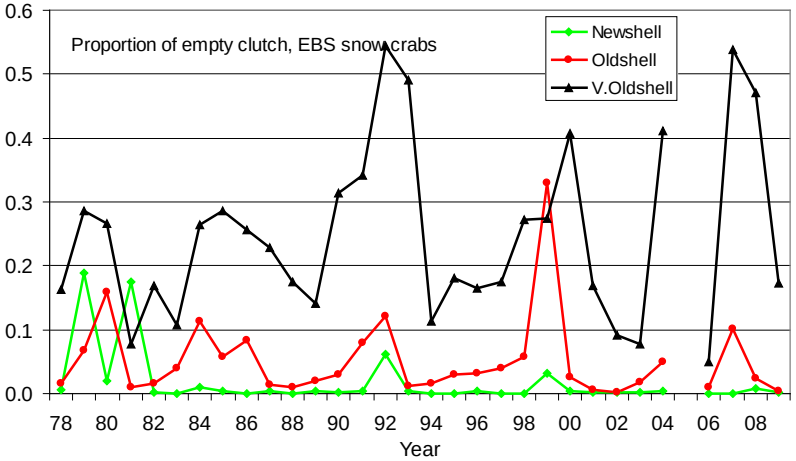
Egg Condition Enter egg condition code:

- 0 - No eggs
- 1 - uneyed eggs
- 2 - eyed eggs
- 3 - dead eggs
- 4 - empty egg cases….

NMFS clutch size codes - *Chionoecetes*

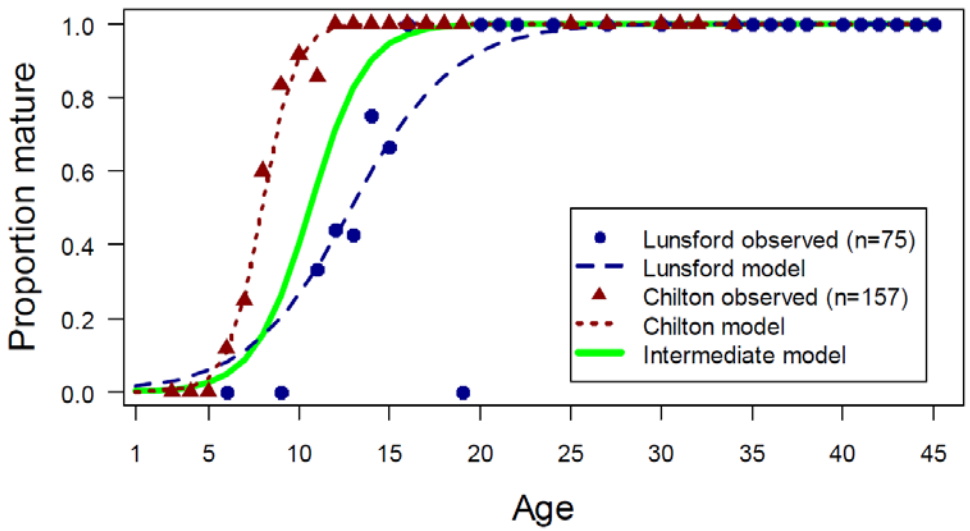


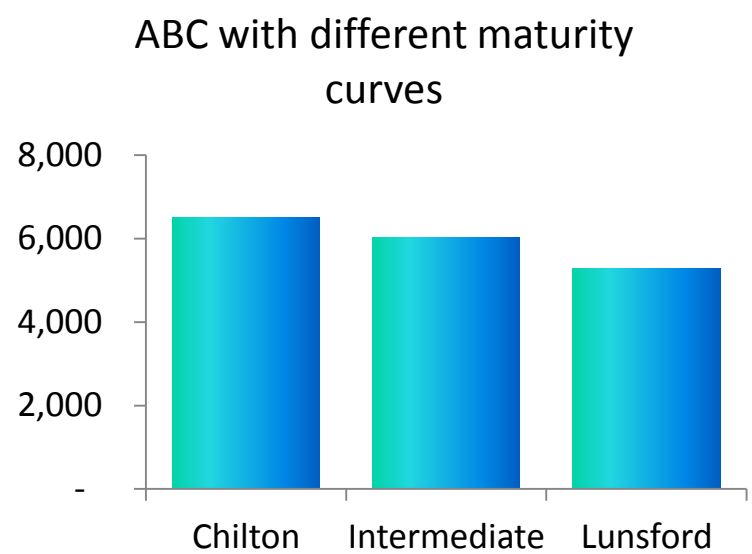




Example GOA northern rockfish:

- Only occasional, small maturity studies
- Estimate maturity-at-age inside model, propagates uncertainty
- Uses two studies together, weighted by sample size
- All GOA rockfish age-at-50% appears lower in recent studies
- Lower M-A-A yields larger ABC (higher $F_{40\%}$)



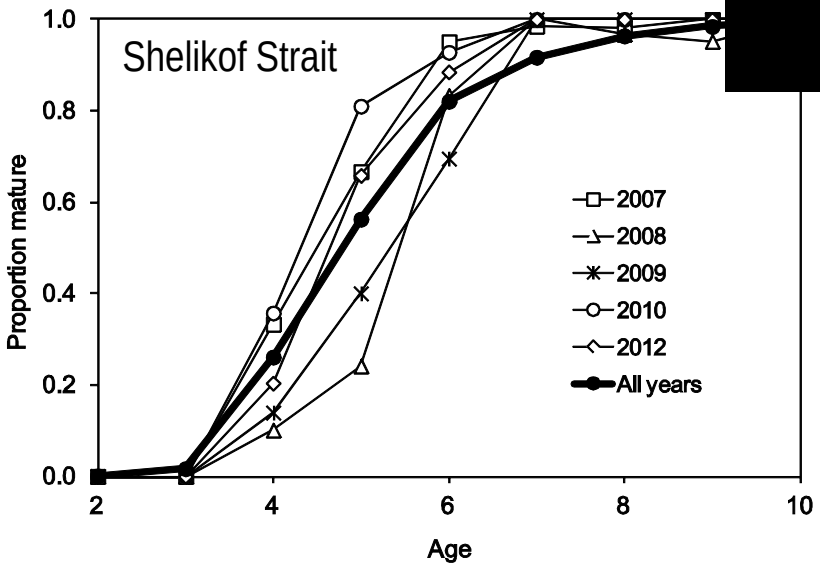


EBS Pollock

Where time series exist, interannual variability observed.

[redacted]

GOA Pollock



Spencer and Dorn Fisheries Research 2013

Index of Reproductive Potential	Maturity ogive	Fmsy	F40%
BSAI POP			
SSB	Based on GOA	0.081	0.062
Viable larvae	Based on GOA	0.079	0.053
GOA Pollock			
Eggs	Average 83-10	0.177	0.198
Eggs	Time varying	0.12	0.197
SSB	Average 83-10	0.173	0.201
SSB	Time varying	0.117	0.199

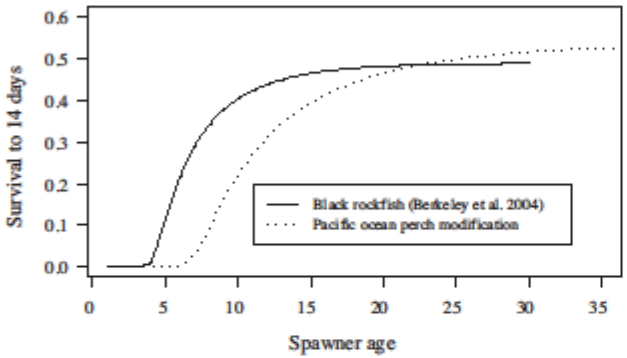


Fig. 1. Survival to viable larvae as a function of spawner age for black rockfish (from Berkeley et al., 2004) and a hypothesized curve for Pacific ocean perch.

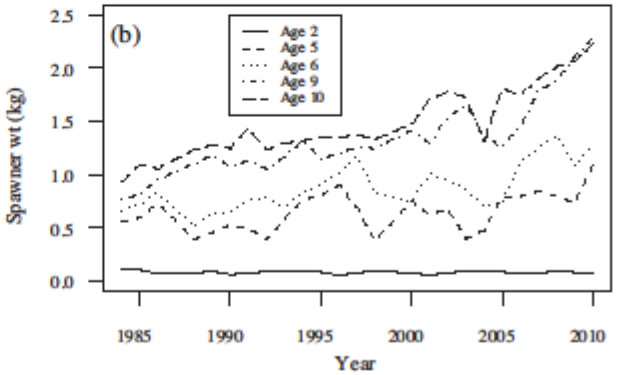


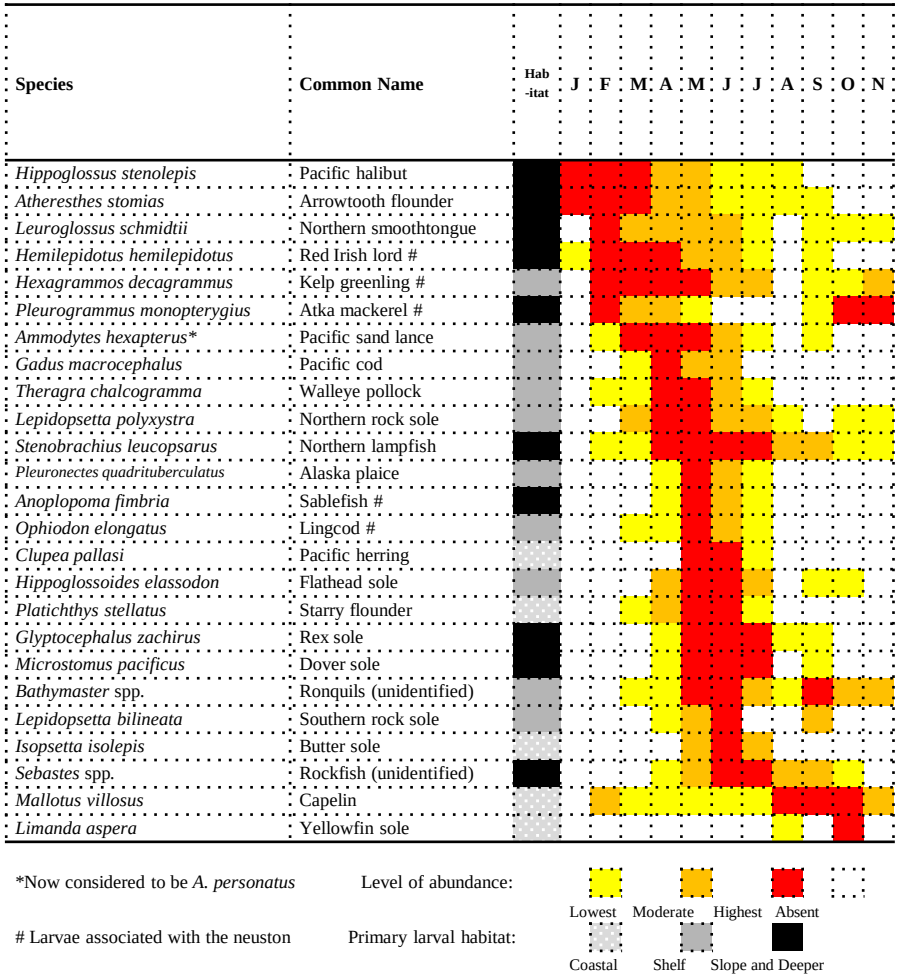
Fig. 2. Walleye pollock age at 50% maturity by year and cohort (a) and temporal trends in spawner weight by age (b).

Challenge 1: Data availability

Species	Region	Is maturity available for age or length?	Number of independent maturity	Years in which maturity data collected	Is maturity data used directly in the assessment to
Alaska plaice	BSAI	Age and Length	In Progress	2012-2013	Yes
Arrowtooth flounder	BSAI	Age and Length	1	2008	Yes
Atka mackerel	BSAI	Age and Length	2	1992-1994 & 2002-2004	Yes
Bering Flounder	BSAI	Age and Length	1	2006 & 2007	No
Flathead	BSAI	Age and Length	1	2000	Yes
Greenland Turbot	BSAI	Length	2	1982 and 2007	Yes
Kamchatka flounder	BSAI	Age and Length	1	2007	Yes
Northern rock sole	BSAI	Age and Length	1	2006	Yes
Northern rockfish	BSAI	Age	1	2004 & 2010	Yes
Pollock	BSAI	Age and Length	In Progress	about 20 years	Yes
Pacific cod	BSAI	Length	1	2003	Yes
Pacific ocean perch	BSAI	Age	1	2004 & 2010	Yes
Rougheye/Blackspotted rockfish	BSAI	Age	1	1990s	Yes
Alaska Skate	BSAI	Age and Length	1	2003-2005	Yes
Yellowfin sole	BSAI	Age and Length	1 & In progress	1992-1993 and 2012-2013	Yes
Grenadier	BSAI and GOA	Age	1	2004 and 2006	No
Sablefish	BSAI and GOA	Age	1	1978-1983, 1996-2012	Yes
Sharks	BSAI and GOA	Age	1 each	2004-2007 for spiny dogfish, 1997-2002 for salmon shark	No
Dusky rockfish	GOA	Age	2	1996 and 2000-2001	Yes
Pacific ocean perch	GOA	Age	2	1995-1996, 2009	Yes
Shortraker rockfish	GOA	Length	1	1994	No
Arrowtooth flounder	GOA	Age and Length	2	1993 & 2002-2003	Yes
Dover sole	GOA	Age and Length	1	2000 & 2001	Yes
Flathead	GOA	Age and Length	1	1999	Yes
Northern & southern rock sole	GOA	Age and Length	1	1996 and 1999	Yes
Northern rockfish	GOA	Age	2	1996 and 2000-2001	Yes
Other rockfish	GOA	Age	1	1995	Yes for sharpchin, no for all others
Pacific cod	GOA	Age and Length	1	1998-2004	Yes
Pollock	GOA	Age and Length	In Progress	28 Years	Yes
Rex sole	GOA	Age and Length	1	2000-2001	Yes
Rougheye/Blackspotted rockfish	GOA	Length	1	1994	Yes
Thornyheads	GOA	Length	2	1995 and 2000	No

Challenges continued

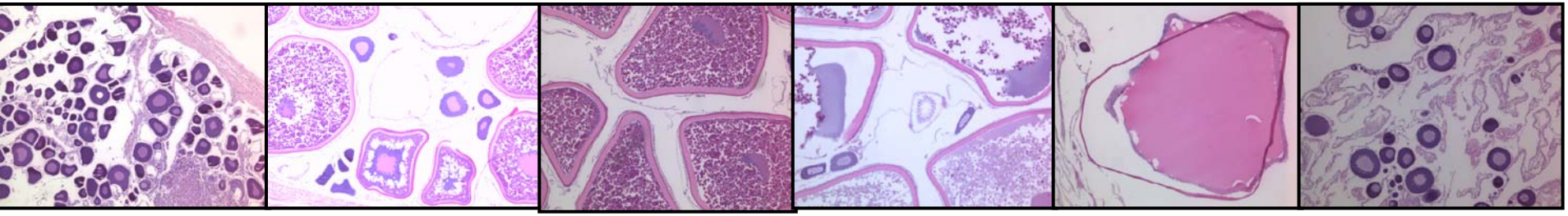
Seasonal Larval Distributions for GOA



- Fishery independent collections on surveys occur after peak spawn timing for most groundfish and crab stocks.
- Identifying the timing and location of parturition for rockfish is difficult.
- For some species peak spawn timing based on historical ichthyoplankton collections. Rockfish larvae are difficult to identify.

Challenges - Continued

1. Histological studies are costly and they are often conducted in only a few selected years.
2. Collections of maturity data by observers is problematic.
    1. Some fishers are reluctant to allow formalin on deck.
    2. Observers are fully occupied with standard data collections.
3. Visual scans require validation.



Perinuclear (NYolk)

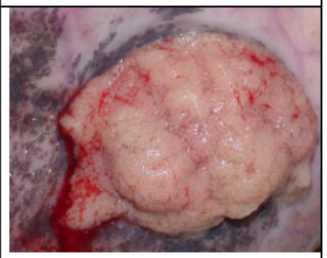
Cortical alveoli (Eyolk) Early vitellogenesis

Med vitellogenesis (MYolk) Nuclear migration

Late vitellogenesis (Lyolk) Yolk fusion YC

Hydration (HYD)

Post-ovulatory Follicles (POF)

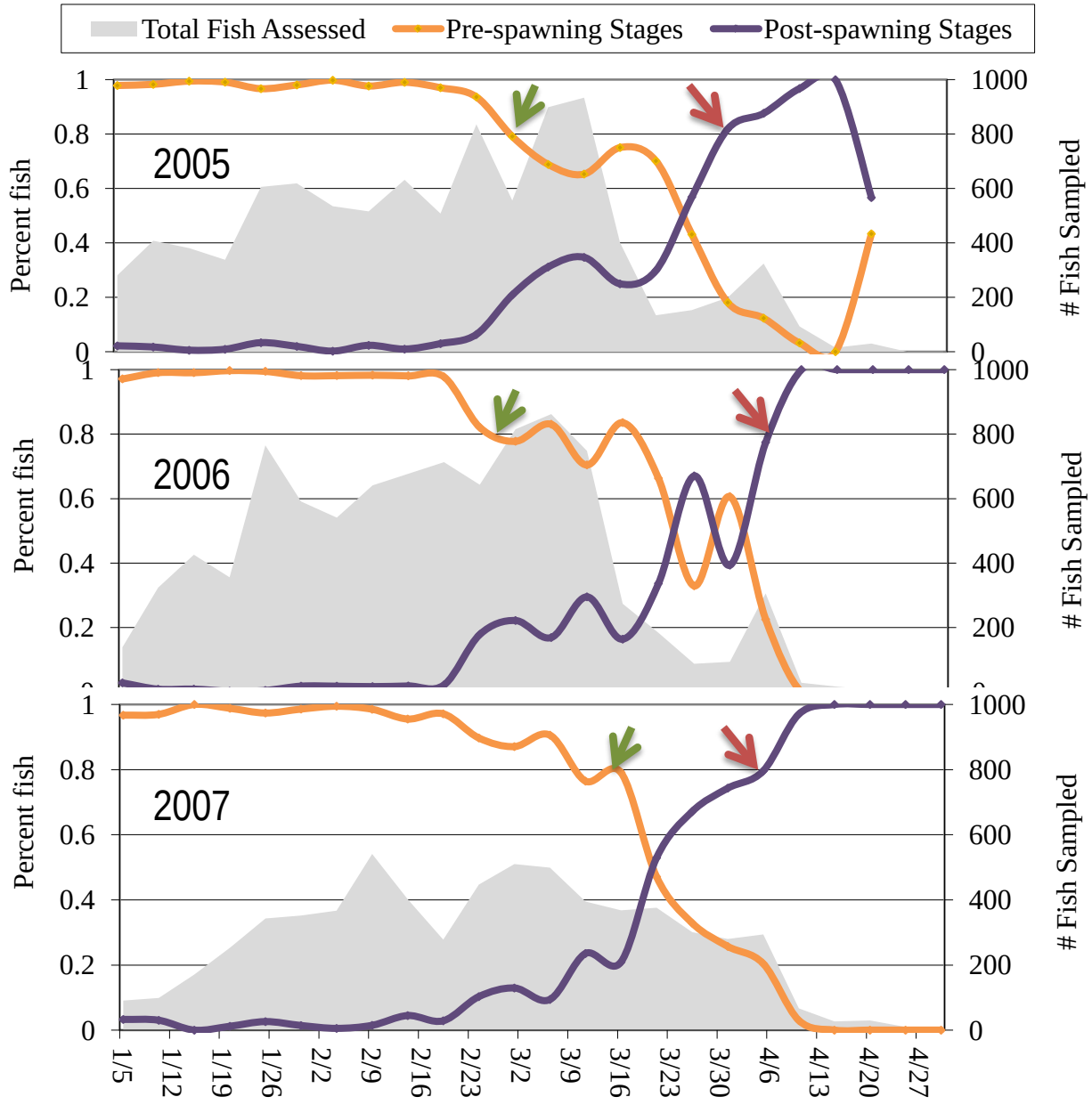
PACIFIC COD MATURITY CODES (FEMALES)		
1. Immature Gonads small, close to vertebral column, may be difficult to sex. Ovaries appear as pink or transparent paired sacs, no oocytes are visible to the eye.		* Look for transparent or pinkish coloration. There may be slight silver or dark blotching on the surface, but the ovary should be small and new looking as shown.
2. Developing Gonads small, to about ½ the length of body cavity. Ovaries form 2 tapered, distinct lobes having well-developed blood vessels. Transparent and/or opaque orange oocytes are distinct and visible through the ovary wall. Oocytes stuck together forming a solid mass. * The ovary shown is fairly small, as stated above the developing ovary can be up to half of the body cavity		
3. Pre-Spawn Ovaries form 2 large distinct lobes. Most eggs appear as mature clear ova, some oocytes remain interspersed throughout the ovary. Ova are less adhesive resembling the consistency of pudding.		
4. Spawning Eggs run under slight pressure to the body. Ova are loose in the ovary.	* No photo available for spawning females though the ovaries look very much like the stage 4 ovary shown above. Spawning fish often release their eggs as they die in fishing gear.	* To differentiate ovary stages 2 through 4 look at the adhesive quality of the eggs. Stage 2 eggs form a solid mass while stage 3 eggs are looser and stage 4 eggs flow freely.
5. Spent Gonads are still large, but appear flaccid and watery. Ovaries may contain remnants of disintegrating ova and associated structures.		* Spawning females who have released their eggs (as mentioned above) should still have some loose eggs in the ovary, with the ovary very flaccid. The ovary starts to shrink, looking wrinkled or bumpy as in the example. Disintegrating ova and structures look bloody.
6. [Resting] Ovaries small, firm, may have some black or silver color. No oocytes are visible to the eye.		* Look for small ovaries (as shown or slightly larger) in larger fish. The surface will be dark or silver and fibrous. The shape is more triangular and thicker than an immature ovary.

- **Immature**: small and transparent
- **Developing**: up to ½ length of abdominal cavity, orange, tightly bound
- **Prespawning**: greater than ½ length of abdominal cavity, opaque, loosely bound
- **Spawning**: free flowing under light pressure

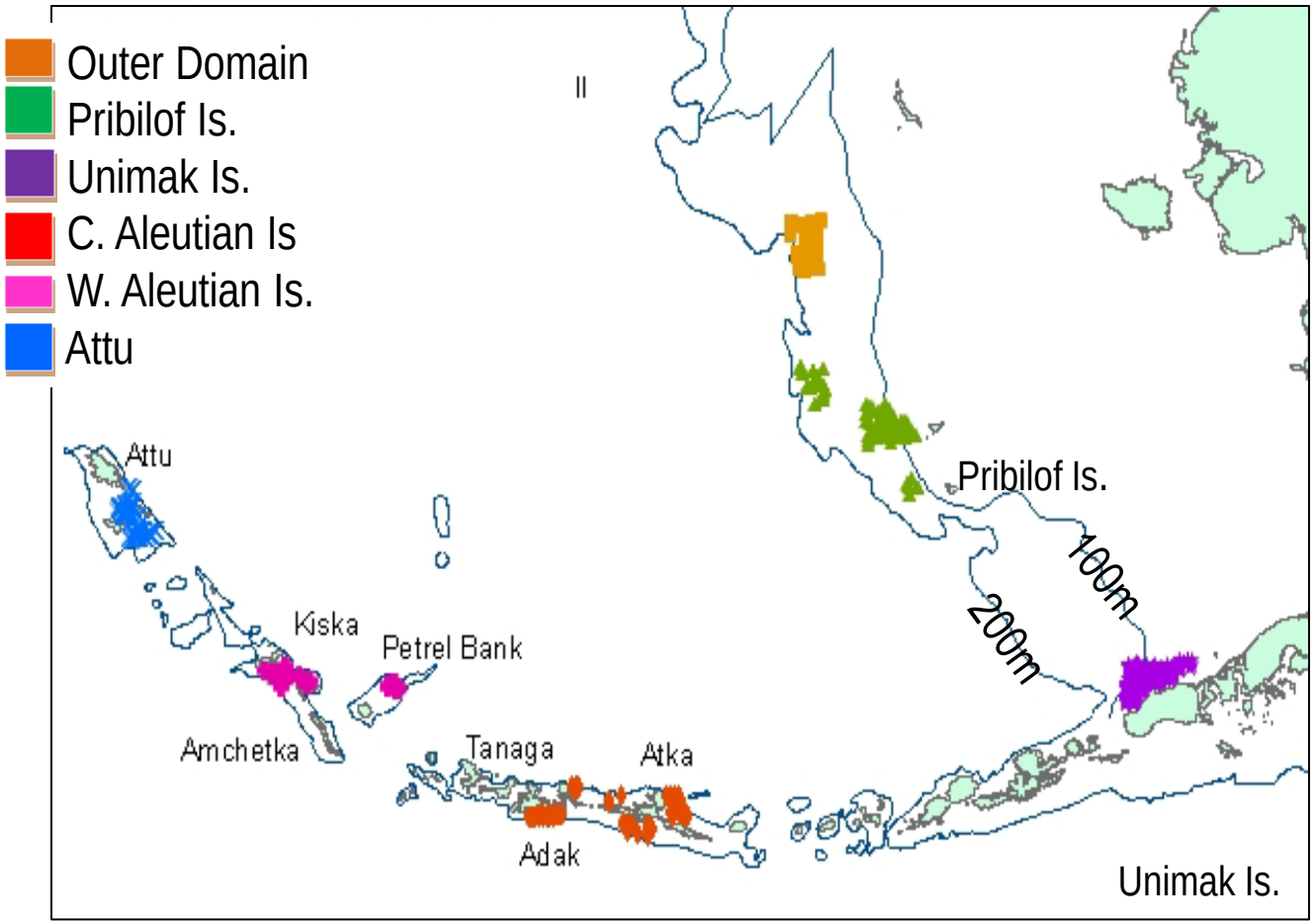
  : small, flaccid, and bloody
- **Resting**: Small, dense, dark

Pacific cod spawning phenology using NMFS observer visual maturity stage assessments for the Bering Sea and Aleutian Islands

- Earlier start to spawning in 2005 (warmer year)
- Longer spawning season in 2006 (transition year)
- Delayed start and shorter duration in 2007 (colder year)



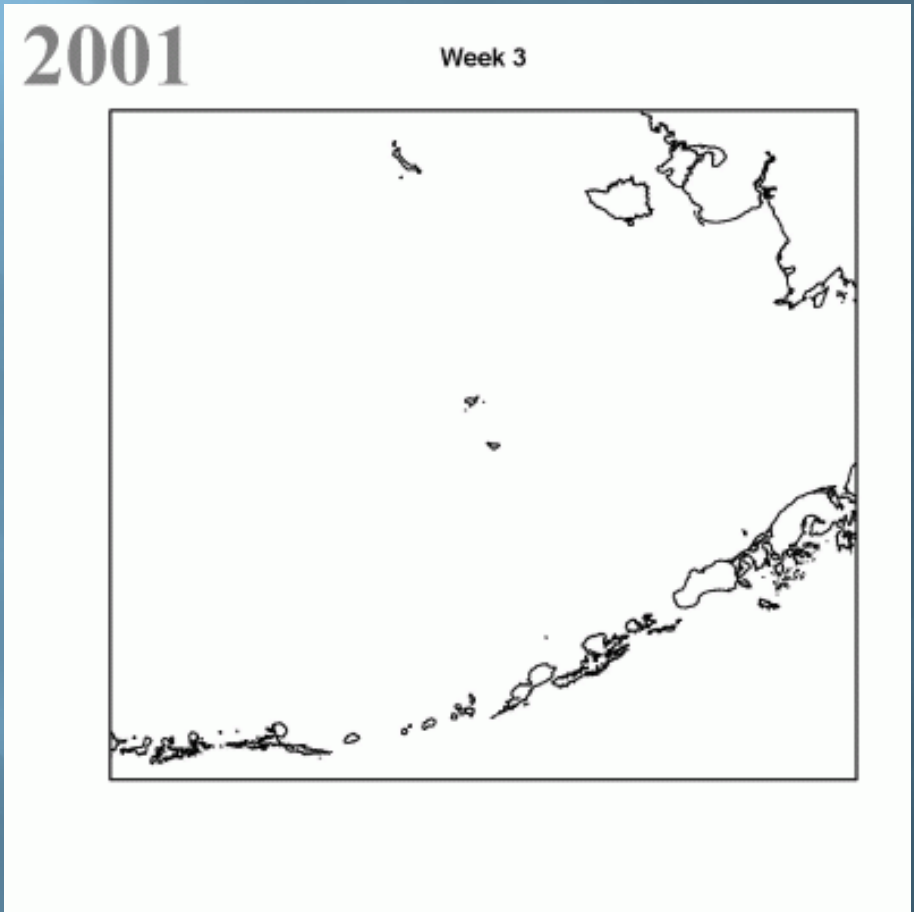
2005 Pacific cod spawning hot spots identified by observer assessed maturity



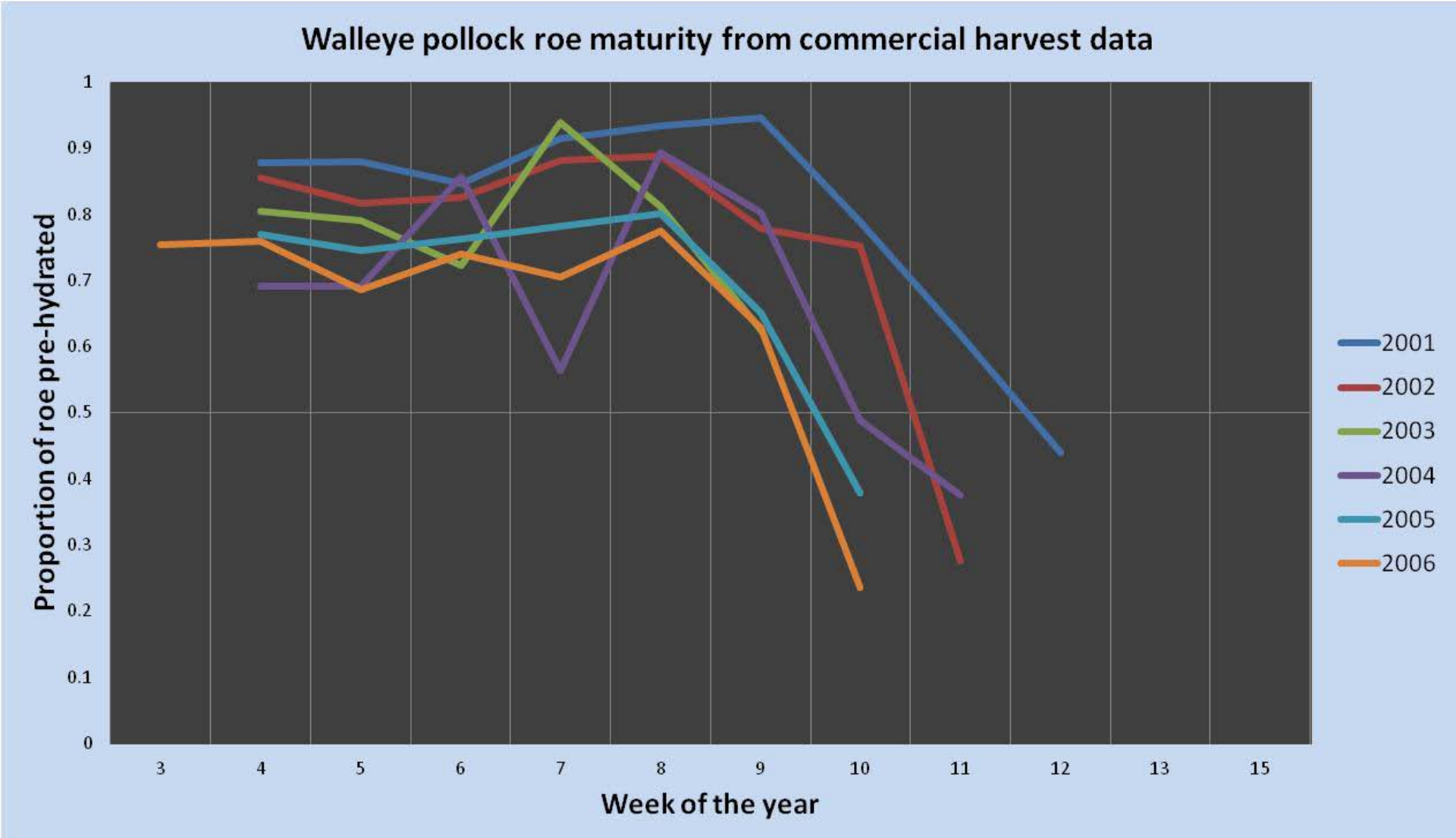
Month	Week	Outer Domain	Pribilof	Unimak	Central Aleutians	Western Aleutians	Attu
February	3						
	4						
March	1						
	2						
	3						
	4						
April	1						

Spawning phenology for hot spot location showing peak spawning

EBS 2001-2003 winter pollock spawning location based on observer samples for weeks 3-13



Cooperative Research - Spawn timing



Solutions - Groundfish

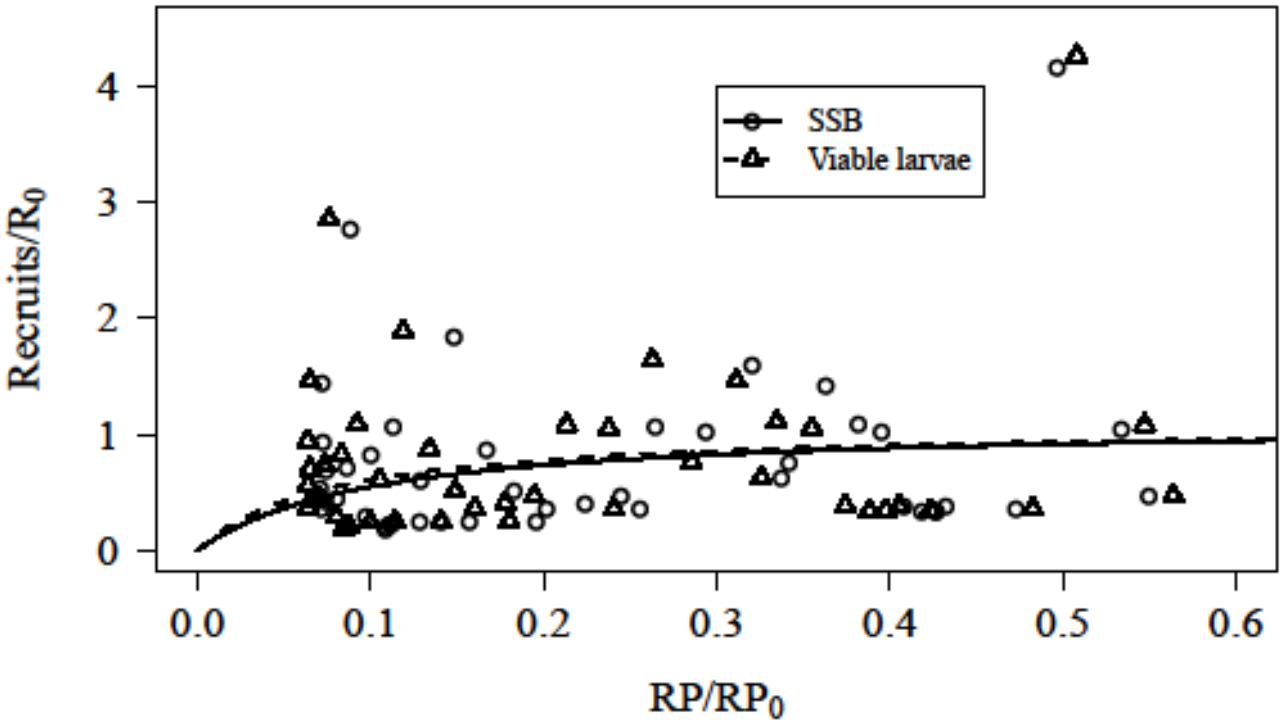
- Verify visual scans, and add collection of maturity data to observer data protocols for winter/spring fisheries.
- Identify opportunities for cooperation with industry to evaluate roe quality indices as markers for maturity schedules.
- Continue histological studies where visual scans can't be verified.
- Conduct blood assays to assess hormonal indices as markers of maturity schedules to facilitate summer data collections.
- For rockfish conduct cooperative research projects to collect information on spawn locations and timing.
- Continue bio-energetic studies and retrospective studies to understand how density independent and density dependent factors influence interannual variability in maturation schedules.

Solutions - Crab

- Verify molting probabilities and evaluate density dependent and density independent influences.
- Conduct tagging studies to estimate probability of encounter.
- Monitor female fertilization fractions,% barren, sperm reserves, and paternity.
- Based on retrospective studies using data collections noted above, estimate fertilized egg production.
- Correct FEP for environmental effects such as temperature effects on biennial spawning.

Extra Slides

Spencer and Dorn 2013

"For BSAI Pacific ocean perch and GOA pollock, estimates of recruitment strength and the variation around stock–recruitment curves were relatively insensitive to various indices of reproductive potential. However, weight-specific relative fecundity increased estimates of Fmsy, whereas maternal effects decreased estimates of Fmsy."

BSAI Pacific Ocean Perch