Using a spatial stock assessment to examine regional biomass and reference points for north Pacific Sablefish (*Anoplopoma fimbria*)

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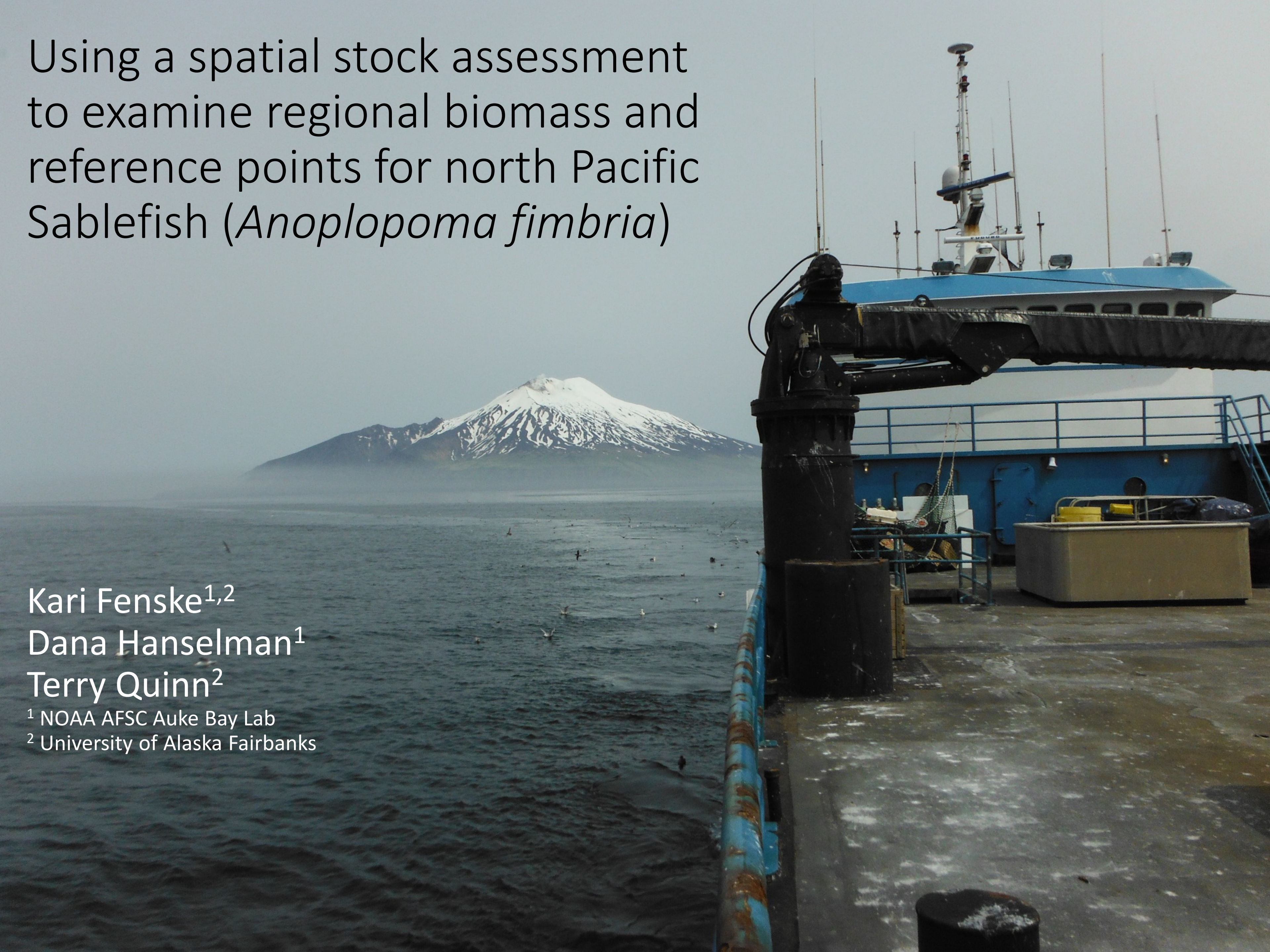


Introduction – Today's outline

Big picture overview

1. Sablefish spatial stock assessment
2. Spatial reference points
3. SPASAM collaborative project
   - Spatial Processes And Stock Assessment Methods (SPASAM)
   - Funded by HQ
   - PIFSC, AFSC, NWFSC, SEFSC, NEFSC and a Post-Doc
4. What does it all mean?

Introduction

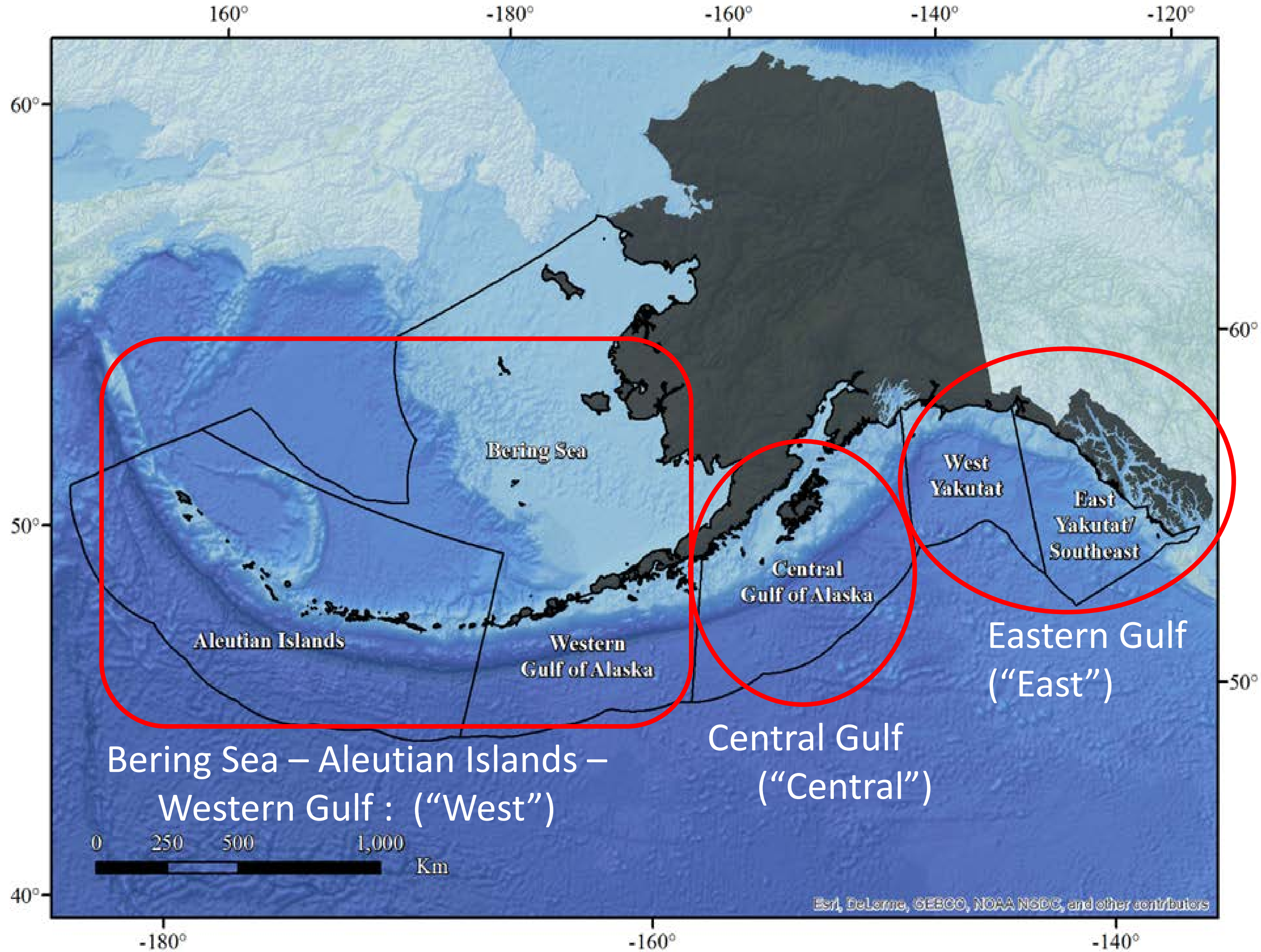
Why do a spatial model?

- Because sablefish move …
- Movement combined with spatial differences in harvest can have consequences to regional biomass.
- IFQ tied to specific regions.

Methods – Spatial model

Three areas

Management boundaries, not biological boundaries



Methods – Spatial structure

Spatial components:

- Annual spatial recruitment deviations from the mean (for 3 areas)
- Catchability –
  - US longline fishery pre-IFQ (3 parameters)
  - US longline fishery post-IFQ (3 parameters)
- Selectivity –
  - US longline fishery post-IFQ

Non-spatial components:

- Mean recruitment – (no S-R relationship)
- M fixed at 0.1
- Growth, maturation
- Catchability and selectivity for other indices/fisheries

Methods – spatial model details

- Terminology:
  - SSASA/Spatial – the three area spatial model
  - ASA/Single – a single area model, area-aggregated data from SSASA
  - Management – the Hanselman et al. single area model
- Data through 2015
- Externally estimated movement – single movement matrix moves fish of all ages equally.

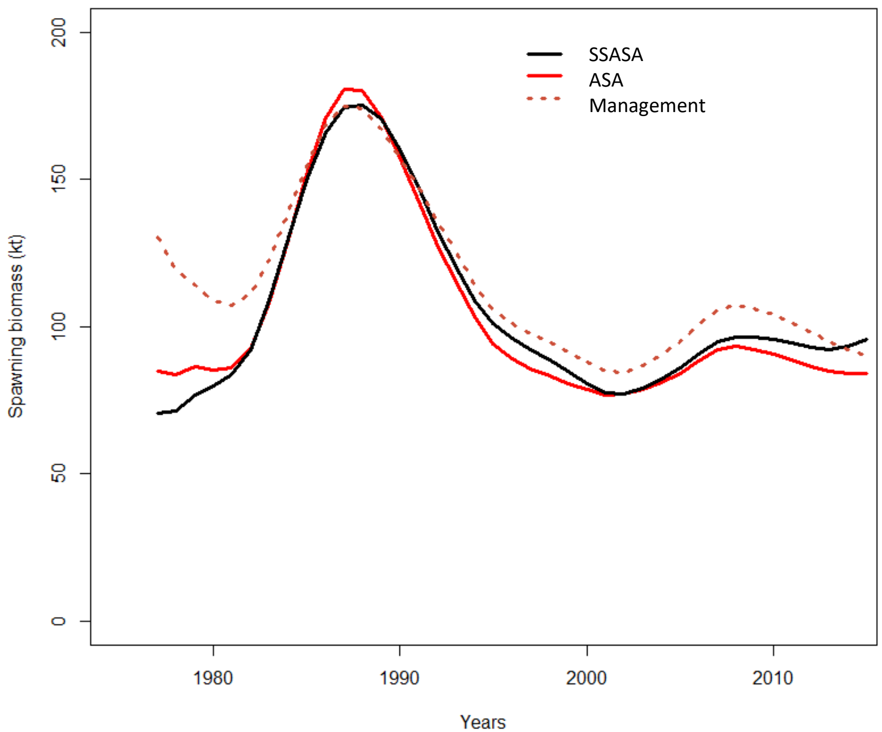
  Move it or lose it: movement and mortality of sablefish tagged in Alaska - Hanselman, Heifetz, Echave, and Dressel, 2015
- Key differences between SSASA and Management models:
  - SSASA starts in 1977 vs. Management model 1960
  - SSASA – no GOA trawl survey index or length comps
  - SSASA – no US-JP survey age comps

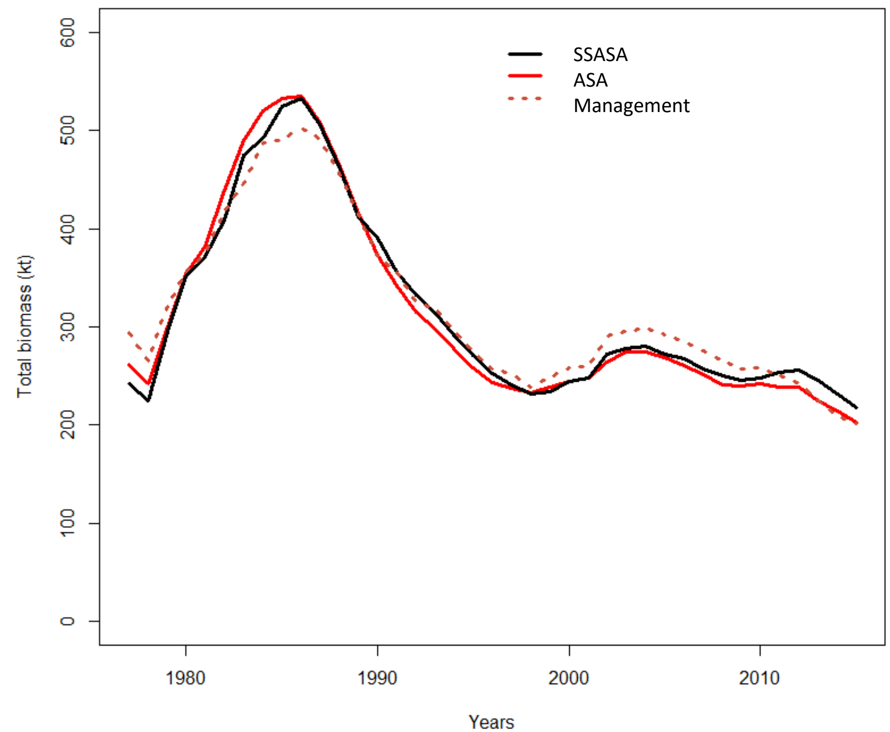
SSASA Results Road Map

1. Model verification
   - SSASA – ASA – Management model comparisons
2. Movement complexity
   - Single movement group vs age based movement
   - Gradient of ‘retention’
3. Model complexity
   - Gradient from simple single area model to a very flexible model

Results – 1. Spatial model vs Management model

Good match between SSASA, ASA, and Management models; validation of model code and structure.



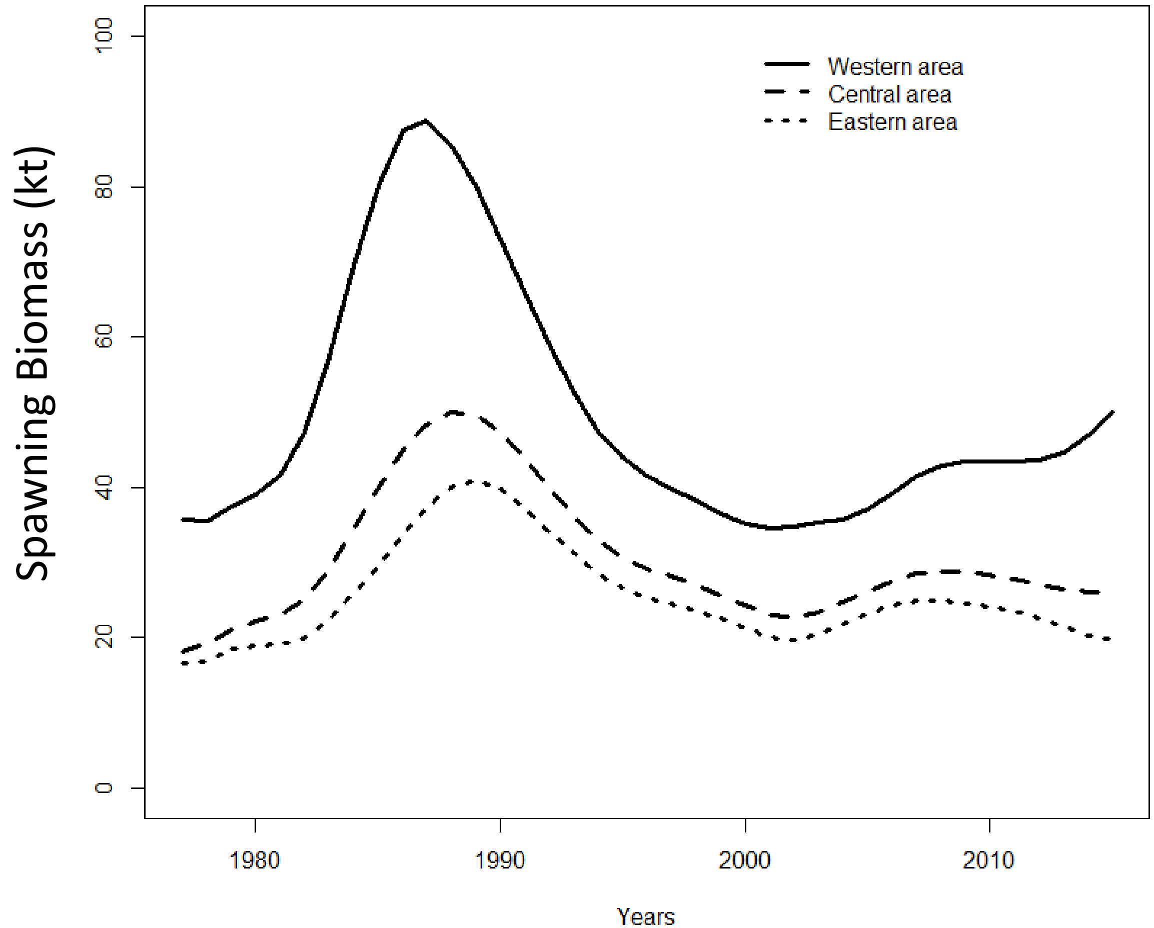


Results – 1. Spatial model vs Management model

SSASA model reveals spatial differences in biomass that can otherwise only be inferred from survey and fishery index data.

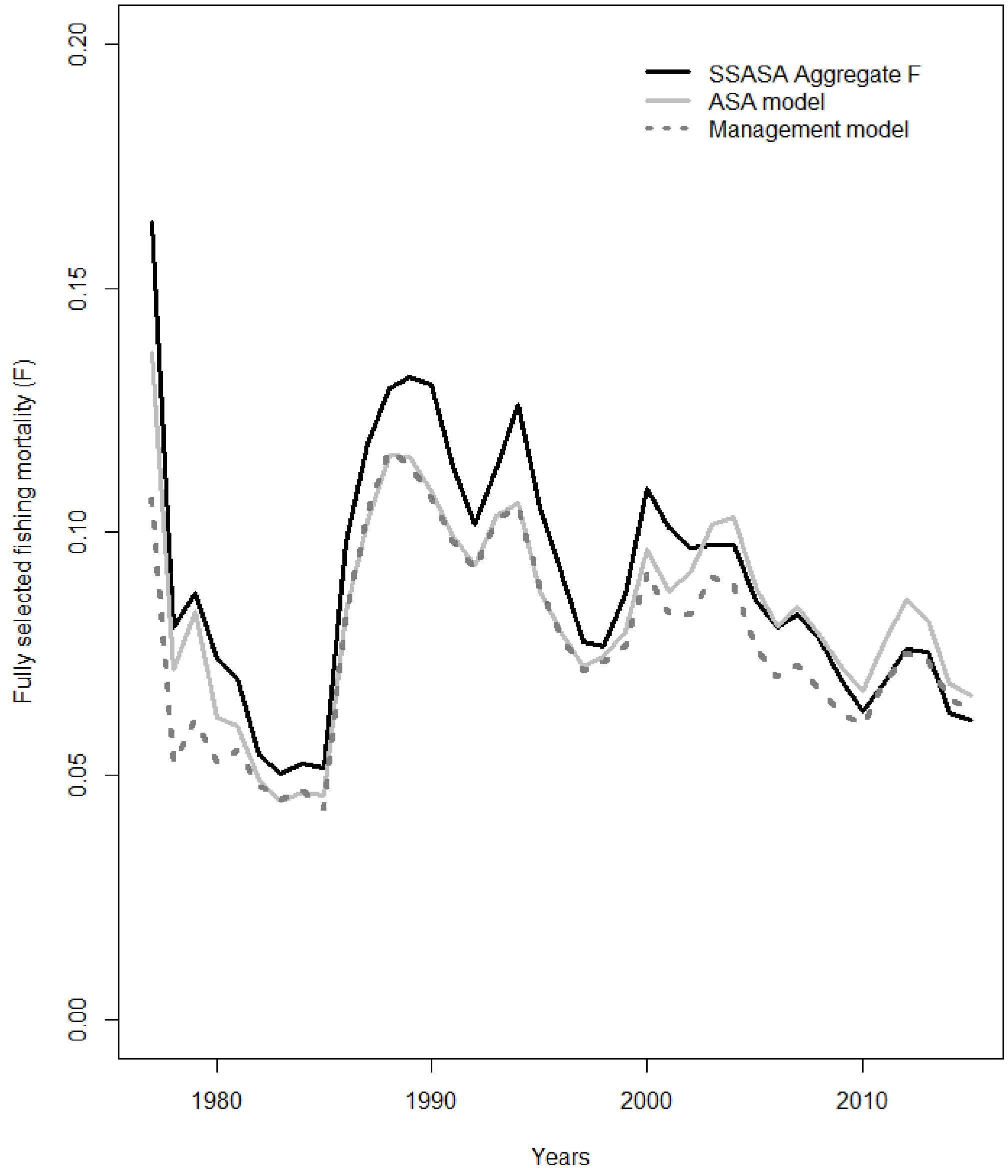
Proportional biomass by area for terminal model year:

	Total biom.	Spawning biom.
West	49%	47%
Central	28%	29%
East	23%	24%



Results – 1. Spatial model

SSASA aggregate F estimates similar to ASA and Management models.



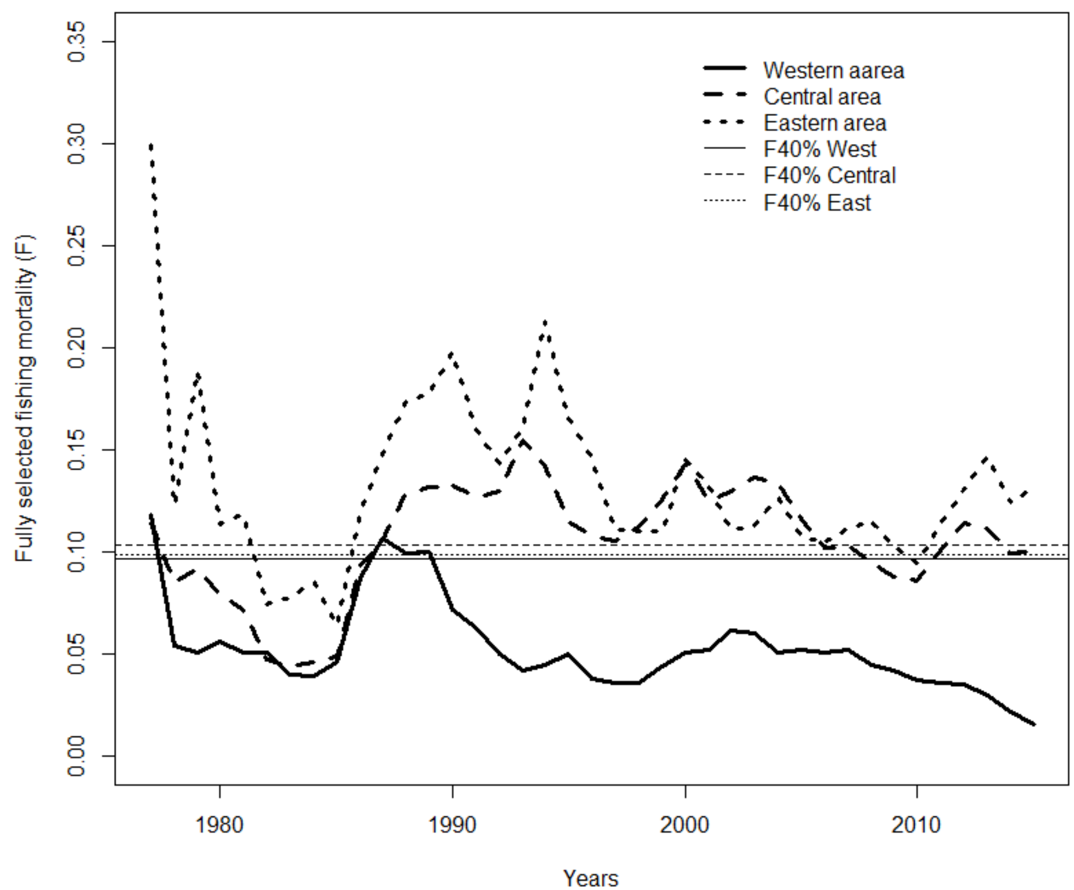
Results – 1. Spatial model

SSASA spatial F estimates match expected values based on observed spatial catches; spatial differences in F relative to F40% reference point.

<u>Total 2015 obs. catch</u>

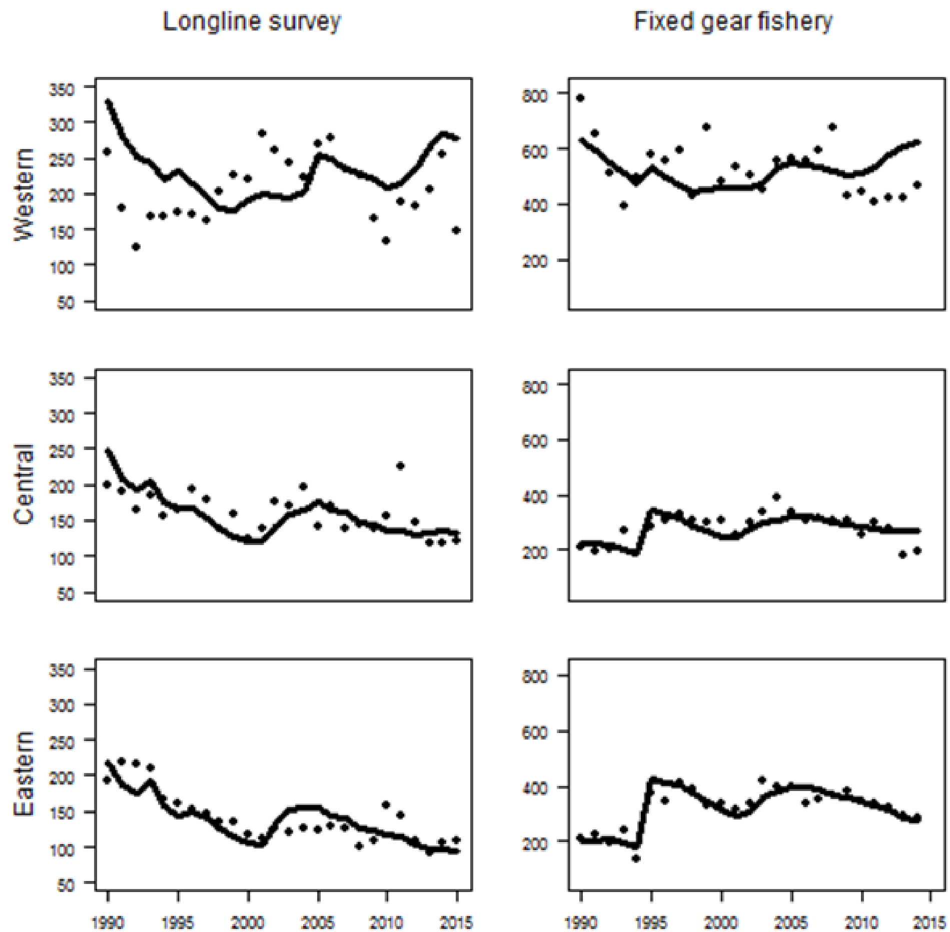
West 1,654 mt
Cent 4,646 mt
East 4,671 mt

Total 10,971 mt



Results – 1. Spatial model fits to data

- SSASA model fits index data well for Central and East regions, poorer fits for West.
- Reveals the difficulty in fitting data from West – forcing fit here compromises other data (catch, composition data)…data conflicts.
- Is this an indication that maybe combining BS, AI, and WGOA isn't best biologically even though it works well for data?
  - Splitting into >3 areas is a challenge
- Despite sablefish being data rich there are still challenges getting good samples sizes of spatial data and estimating spatial parameters!



Results – 2. Spatial model: movement complexity

Movement matters! Perceptions of regional and Σ (region) biomass change based on movement rates.

Alternative age-based movement rates lead to lower estimates of SB vs. the SSASA spatial model. In addition, depletion ($SB_{2015,r}/B_{40,r}$) was greater for age-based movement alternatives (not shown).

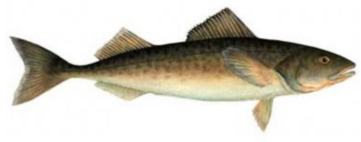
Methods:

Sensitivity runs of three alternate age based movement groups

- Use different methods to convert the length-based movement from Hanselman et al. to ages based on:

A. Female length at age
B. Male length at age
C. Mean length at age

Model	Spawning biomass$_{2015}$ Σ (region)
SSASA base	95.8
ASA	84.1 (-12%)
Management	90 (-6%)
Age-based mvmt. A	65.2 (-32%)
Age-based mvmt. B	83.9 (-12%)
Age-based mvmt. C	71.2 (-26%)



Results – 2. Spatial model: movement complexity

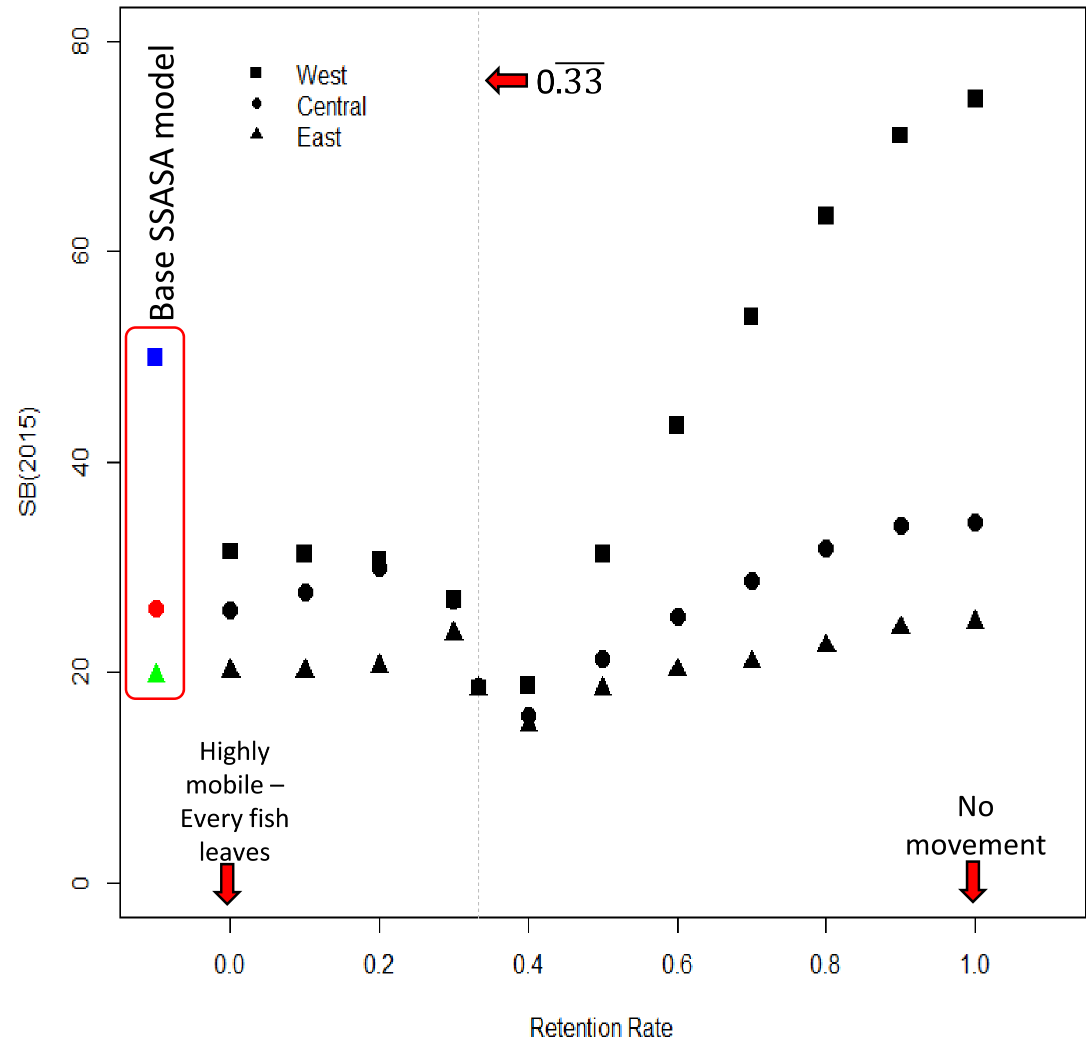
Movement matters! Getting movement rates wrong can greatly alter perceptions of spatial biomass.

Methods:

Twelve sensitivity runs along a 'gradient of retention', *x*, where

$0 \leq x \leq 1$

		To		
		West	Central	East
From	West	*x*	(1-*x*)/2	(1-*x*)/2
	Cent.	(1-*x*)/2	*x*	(1-*x*)/2
	East	(1-*x*)/2	(1-*x*)/2	*x*



Methods – 3. Spatial model: model complexity

Model complexity matters!

Methods:

Twelve sensitivity runs along a gradient from a simple single area model to a very spatially complex model.

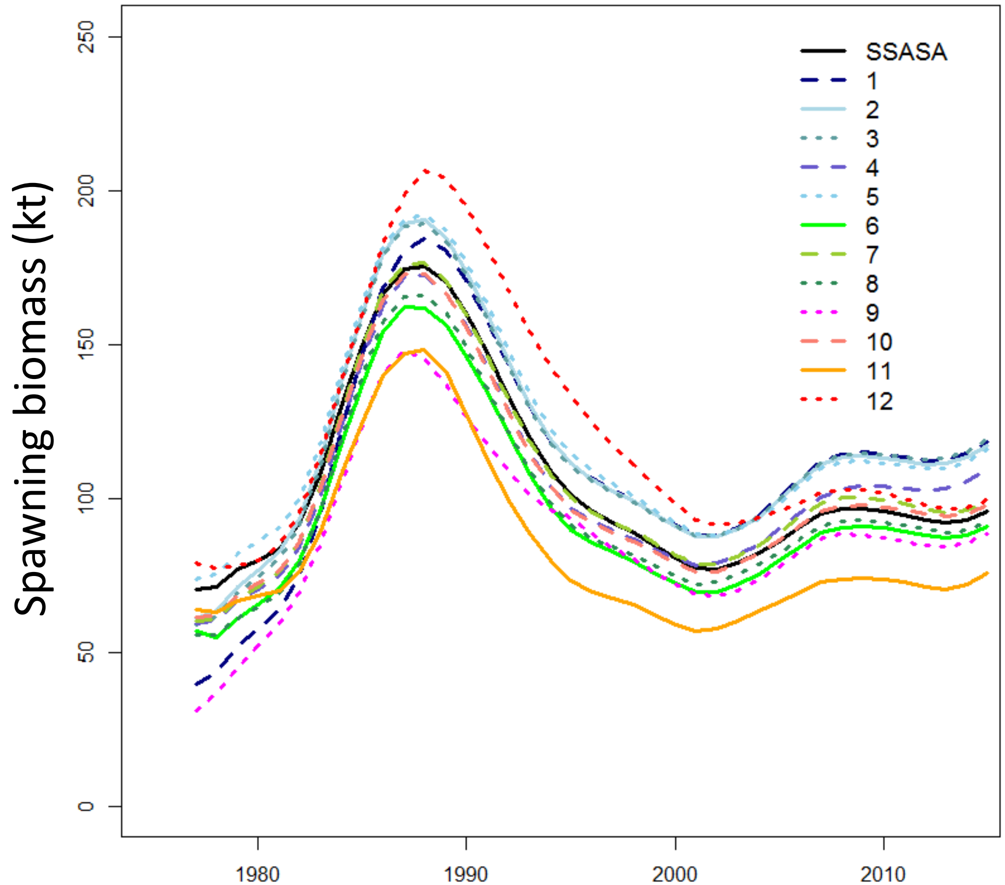
Pre = Pre-IFQ fishery
Post = Post-IFQ fisher
Survey = US LL survey

Model	Mvmt.	Spatial Data	Spatial *S*	Spatial *Q*
ASA	N	N	N	N
1	Y	Y	N	N
2	Y	Y	N	Pre
3	Y	Y	N	Post
4	Y	Y	N	Survey
5	Y	Y	N	Pre & Post
6	Y	Y	Pre	N
7	Y	Y	Post	N
8	Y	Y	Survey	N
9	Y	Y	Pre	Pre
10	Y	Y	Post	Post
11	Y	Y	Survey	Survey
SSASA	Y	Y	Post	Pre & Post
12	Y	Y	Pre & Post, Survey	Pre & Post, Survey

Results – 3. Spatial model: model complexity

Model complexity matters! The choice of spatial parameterization can greatly alter perceptions of spatial and Σ (region) biomass.

Model	Mvmt.	Spatial Data	Spatial *S*	Spatial *Q*
ASA	N	N	N	N
1	Y	Y	N	N
2	Y	Y	N	Pre
3	Y	Y	N	Post
4	Y	Y	N	Survey
5	Y	Y	N	Pre & Post
6	Y	Y	Pre	N
7	Y	Y	Post	N
8	Y	Y	Survey	N
9	Y	Y	Pre	Pre
10	Y	Y	Post	Post
11	Y	Y	Survey	Survey
SSASA	Y	Y	Post	Pre & Post
12	Y	Y	Pre & Post, Survey	Pre & Post, Survey



Results – Reference Points

SSASA spatial model gives regional estimate of SB relative to reference points.

SSASA model DOES NOT tell us whether one region contributes more to successful recruitment because there is no spatial data on fecundity or spatial S-R relationship in the model.

Methods:

- Reference points – Tier 3 so looking at F_{40}, B_{40} instead of F_{msy}, B_{msy}.
- F_{40} is the exploitation rate in each spatial area which reduces the female potential spawning biomass per recruit to 40% of the unfished spawning biomass per recruit.
- No spawner-recruit relationship.

Results:

SSASA	SB_{2015}/B_{40}
West	1.54
Central	0.87
East	0.48
ALL	0.82
ASA	0.82
$Mgmt_{2015}$	0.87

Results – Spatial model & Apportionment

SSASA would have led to even higher ABC recommendation in West, lower in East, and almost the same for Central compared to traditional apportionment methods used in the past 5 years.

SSASA spatial model doesn't automatically solve apportionment issues (annual fluctuations in apportionment) but it will help us look at management strategies going forward.

ABC apportionment (t) for 2015 and spatial proportion:

	2015 SSASA	Mgmt Std apport.	Mgmt 'Fixed apport'
West	52%	5,495 (40%)	4,609 (34%)
Central	27%	3,975 (29%)	4,658 (34%)
East	21%	4,187 (31%)	4,390 (32%)

Methods - SPASAM

SPASAM's deep thinkers:



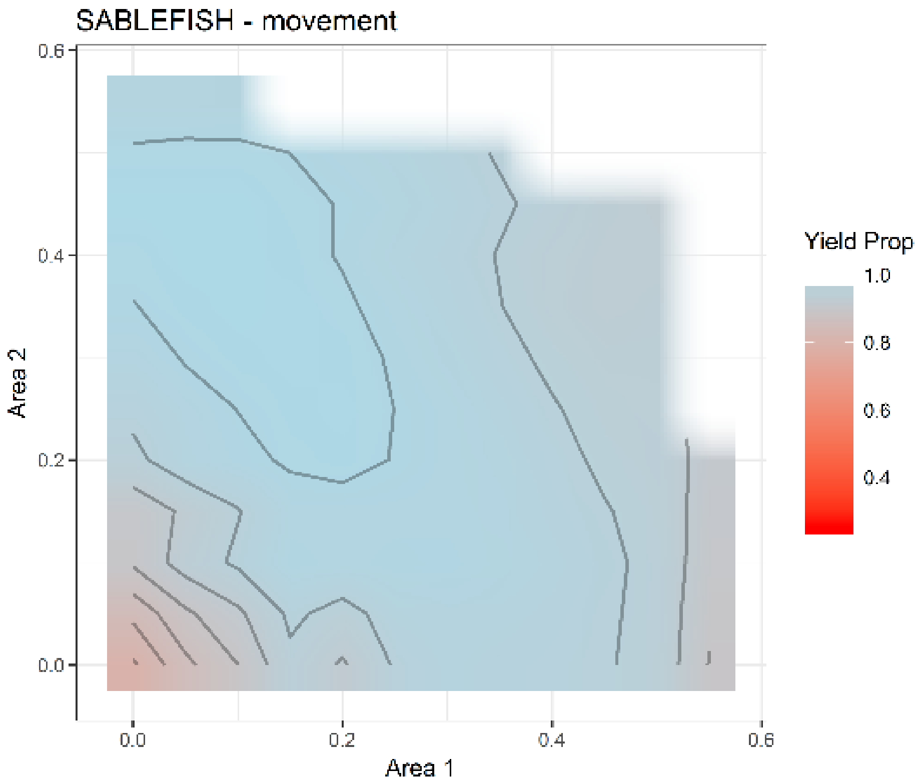


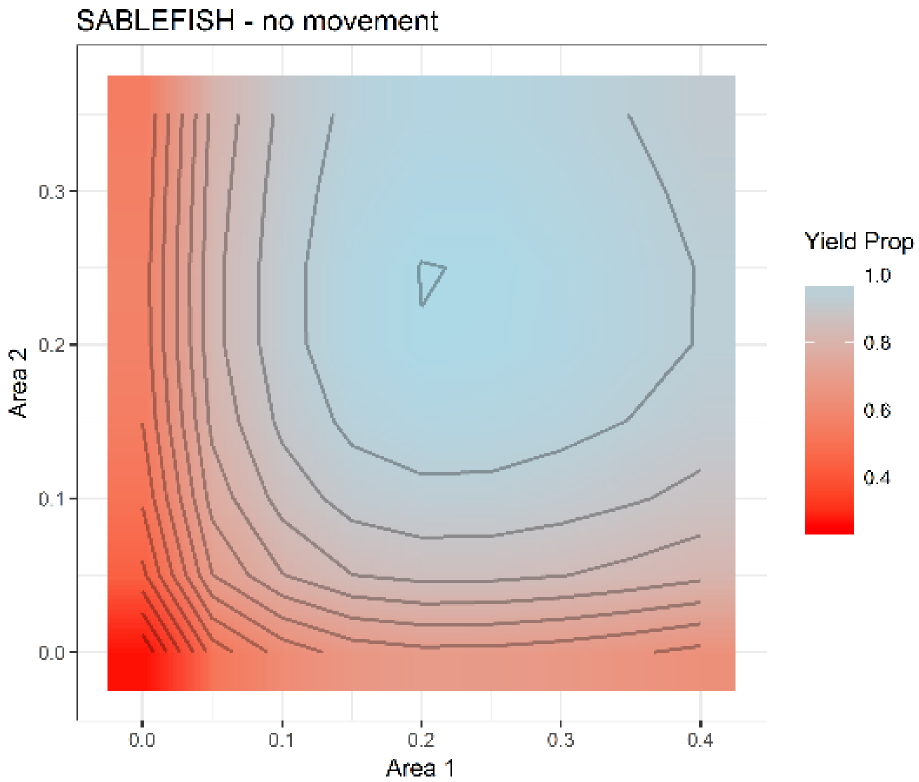



- PIFSC, AFSC, NWFSC, SEFSC, and NEFSC and a Post-Doc – funded by HQ
- Impact of spatial heterogeneity in population parameters (maturity, recruitment, movement, selectivity) on regional yield
- Using a 'sablefish-like' species as one simulation test subject (+ two others)
  - No stock-recruitment relationship
- Two stage approach:
  - Stage 1: Determine regional harvest levels that maximize system yield
  - Stage 2: Use observed data (w/meas.error) to apportion population level ABC to region

Results – SPASAM

SPASAM results suggest for a mobile sablefish-like species, there's a wide range of spatial Fs that will still get you pretty close to MSY.



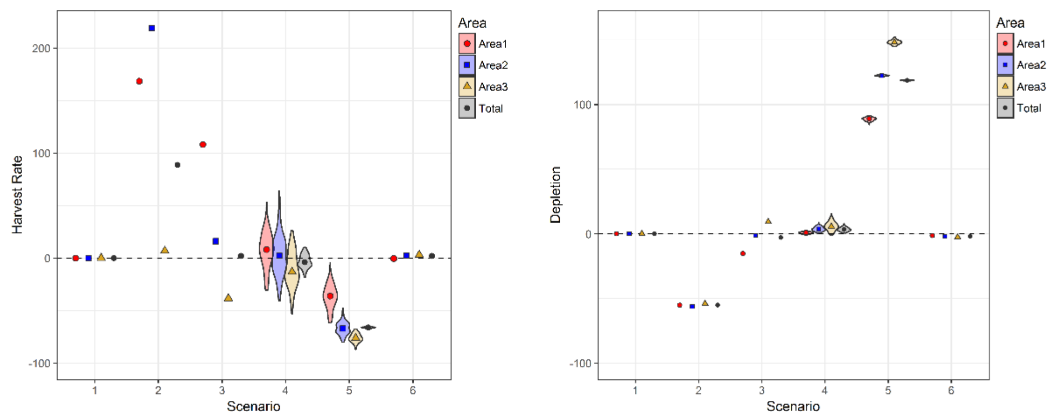


Results – SPASAM

Apportioning pop. level ABC based on relative survey biomass may NOT be better than equal apportionment between areas IF there is connectivity between regions *for obtaining population MSY*.

Simulations apportioning TAC to region under alternate MSY, TAC apportionment methods:

- $ABC_{Region} = u_{MSYPopulation} * Biomass_{Population} * Apportionment_{Region}$
- **Two sources of bias**
  - Allocation of uMSY
  - Biomass allocation



Model #	Simulated Dynamics	uMSY	Biomass Source	TAC Allocation Method
1	Multi-area	regional	regional	None
2	Multi-area	regional	population	None
3	Multi-area	population	regional	None
4	Multi-area	regional	population	Survey biomass
5	Multi-area	population	regional	Survey biomass
6	Multi-area	population	population	Exact Exploitation AND Biomass Apportionments

Conclusions Part I (my 2¢)

1. Don’t move to a spatial model…for now.

Why not?

a) Movement drives results.

b) Need to really nail down movement rates and be able to incorporate movement uncertainty.
   - Tag integrated stock assessment model or
   - Explore sex-specific and age-based movement rates

c) Sablefish movement rates are pretty high within AK federal regions; 2016 CIE reviewers thought the population was probably pretty well mixed and they suggested apportionment may be a socio-economic issue and not biological one thus the single area model would be sufficient…But see 2c…

d) SPASAM group’s work – for a mobile population there are many paths to ~MSY and apportionment.

Conclusions Part II (my 2¢)

2. Spatial models are hard.
   a) Even though sablefish are data rich, more than 3 (maybe 4) spatial areas may be challenging; convergence and sample size issues…but worth exploring further.
   b) Ensemble models with different plausible spatial complexity may be useful when there is uncertainty about spatial parameterization.
   c) Need to better understand recruitment dynamics of sablefish to understand the implications of spatial differences in spawning biomass.
      - Are there spatial aspects of spawning? Are females moving to spawn, particularly between spatial areas? Are females in some areas more fecund/successful than others?
      - These things will influence implications of spatial harvest rates/B_{40} and may indicate the need for spatial linkages between spawners and recruits.
      - Consider continued tagging age-0 fish and satellite tags for mature females, fecundity studies of females on spawning grounds, other studies to shed light on recruitment/spawning success.

   d) Accounting for movement correctly in reference points is complicated…and I am still not sure I am doing it right.
3. Do look at the spatial model as a tool to help understand spatial biomass.
   a) Track regional biomass in conjunction with a single area model.
   b) A spatial model alone won't solve apportionment concerns.
   c) Next step is sablefish-specific simulations looking at apportionment, including scenarios exploring spawn-recruit relationships.

The end

Questions and Discussion

Really interested in reading more? Draft manuscript available for some leisurely reading.

Thank you - Dana and Terry, Jordan Watson, Karson Coutre, and the SPASAM group.

Still the end

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Bonus slides (FREE! *limited time offer, some restrictions may apply)

- Base model movement based on: **Move it or lose it: movement and mortality of sablefish tagged in Alaska** - Hanselman, Heifetz, Echave, and Dressel, 2015

		To		
		West	Central	East
From	West	0.68	0.22	0.10
	Cent.	0.24	0.37	0.39
	East	0.08	0.28	0.64

Bonus slides (FREE! *limited time offer, some restrictions may apply)

- Movement based on: **Move it or lose it: movement and mortality of sablefish tagged in Alaska** - Hanselman, Heifetz, Echave, and Dressel, 2015

Base model:

From	To: West	Central	East
West	0.68	0.22	0.10
Cent.	0.24	0.37	0.39
East	0.08	0.28	0.64

Move by size/age:

Small, Length <57 cm

From:	To: West	Central	East
West	69.4%	18.0%	12.7%
Central	29.4%	32.9%	37.7%
East	22.1%	38.9%	38.9%

Medium, Length 57-66 cm

From:	To: West	Central	East
West	61.6%	24.1%	14.2%
Central	27.4%	33.9%	38.8%
East	11.9%	27.2%	60.9%

Large, Length > 66 cm

From:	To: West	Central	East
West	50.1%	24.8%	25.1%
Central	22.3%	31.1%	46.6%
East	14.6%	28.2%	57.1%

Profile of retention rates:

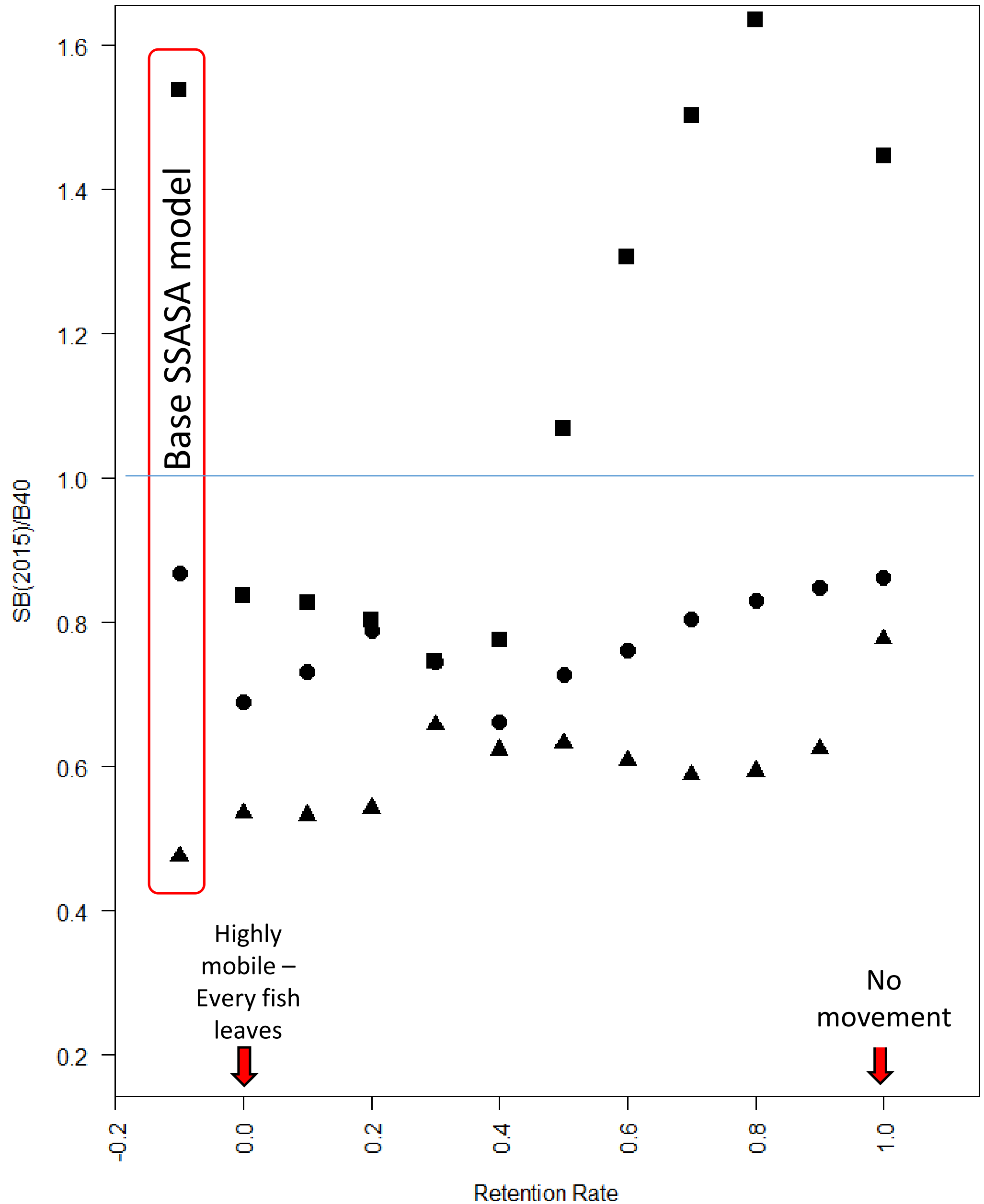
From	To: West	Central	East
West	x	$(1-x)/2$	$(1-x)/2$
Cent.	$(1-x)/2$	x	$(1-x)/2$
East	$(1-x)/2$	$(1-x)/2$	x

Results – 2. Spatial model: movement complexity

Looked at movement complexity in a few ways:

2. Gradient of ‘retention’, *x*, where 0 ≤ x ≤ 1, plus a bonus run at 33% retention (‘well mixed’)

Now looking at SB_{2015}/B_{40} “Depletion”



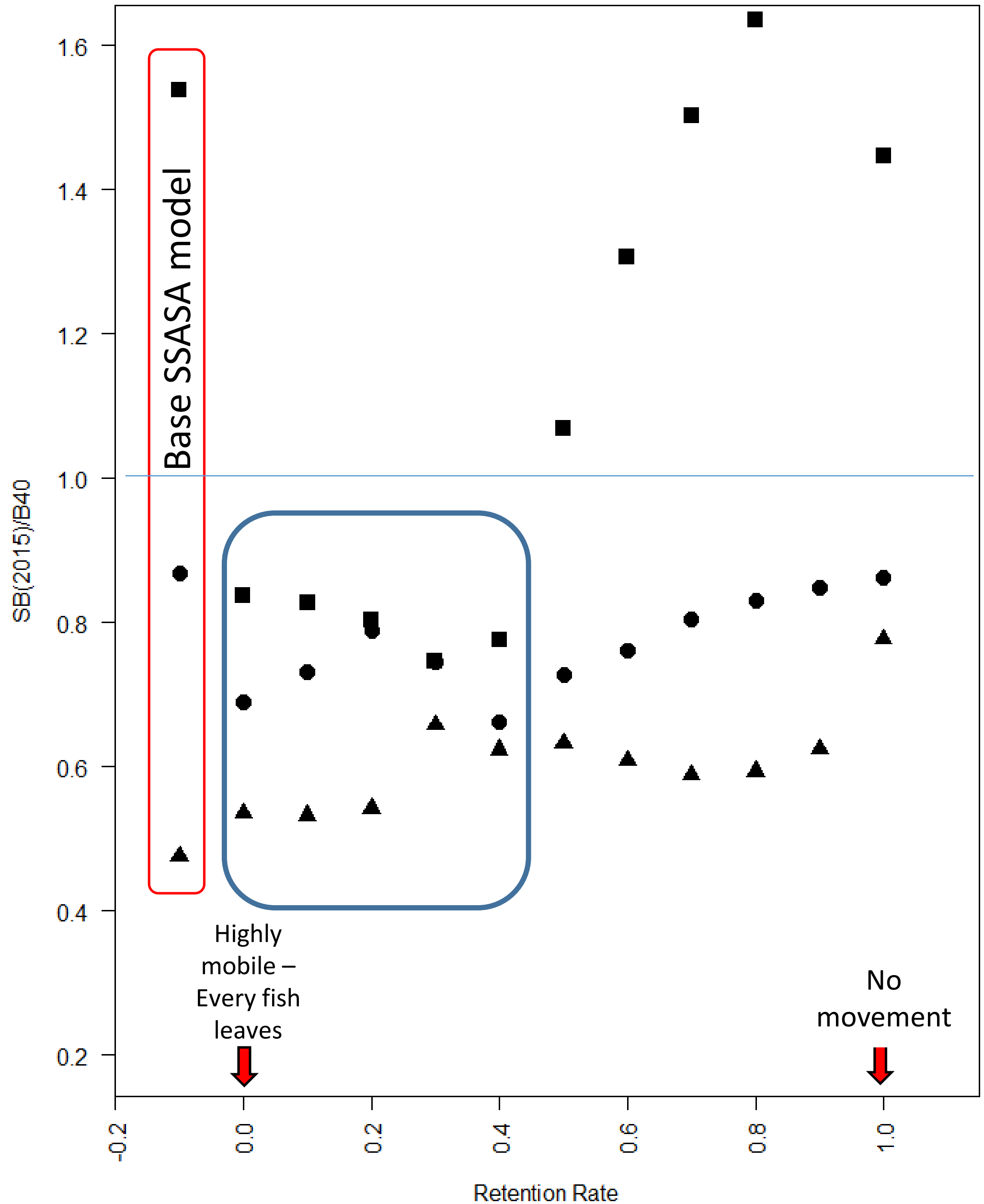
Results – 2. Spatial model: movement complexity

Looked at movement complexity in a few ways:

2. Gradient of ‘retention’, *x*, where $0 \le x \le 1$, plus a bonus run at 33% retention (‘well mixed’)

Results summary:

- High movement rates (low retention) leads to all regions below B40 reference point.



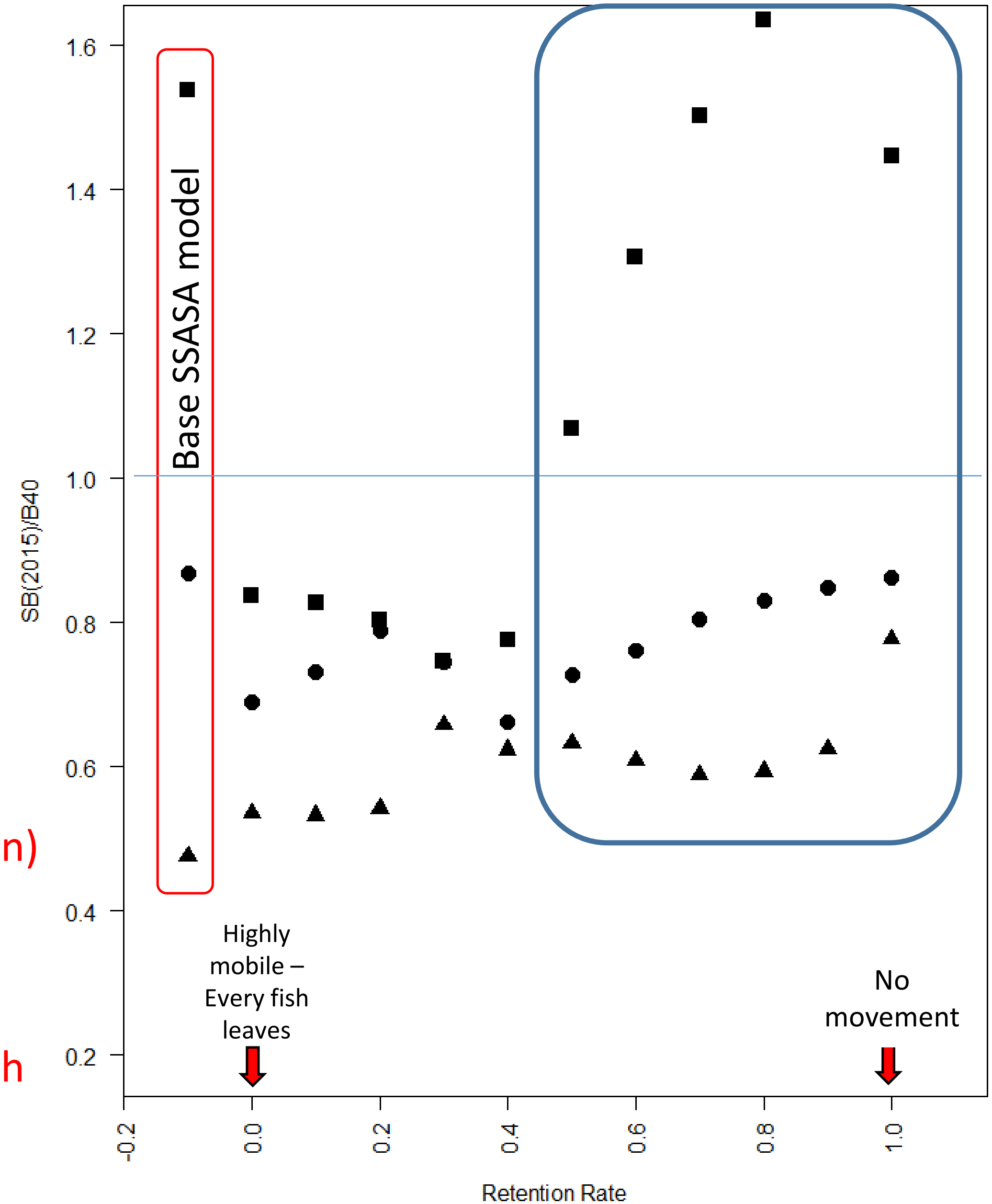
Results – 2. Spatial model: movement complexity

Looked at movement complexity in a few ways:

2. Gradient of 'retention', *x*, where 0 ≤ x ≤ 1, plus a bonus run at 33% retention ('well mixed')

Results summary:

- High movement rates (low retention) leads to all regions below B40 reference point.
- Lower movement rates (high retention) leads to East and Central below B40 reference point, West is above.
- Start to see the interaction of movement (or lack of movement) with spatial F, selectivity, and recruitment.



Results – 3. Spatial model: model complexity

Model	Mvmt.	Spatial Data	Spatial *S*	Spatial *Q*	SB_{2015} (% change from SSASA base) West SB	Central SB	East SB	Σ (region)
ASA	N	N	N	N				84.1 (-12)
1	Y	Y	N	N	63.3 (+27)	31.7 (+21)	23.5 (+19)	118.5 (+24)
2	Y	Y	N	Pre	62.6 (+25)	31.3 (+20)	23.2 (+18)	117.2 (+22)
3	Y	Y	N	Post	65.1 (+30)	31.6 (+21)	22.6 (+15)	119.4 (+25)
4	Y	Y	N	Survey	64.1 (+28)	27.6 (+6)	17.9 (-9)	109.6 (+14)
5	Y	Y	N	Pre & Post	63.1 (+26)	30.7 (+18)	22.0 (+12)	115.8 (+21)
6	Y	Y	Pre	N	46.6 (-7)	25.0 (-4)	19.2 (-3)	90.8 (-5)
7	Y	Y	Post	N	49.9 (0)	27.3 (+5)	21.6 (+10)	98.7 (+3)
8	Y	Y	Survey	N	34.1 (-32)	22.7 (-13)	19.6 (-1)	76.5 (-20)
9	Y	Y	Pre	Pre	46.9 (-6)	23.7 (-9)	18.1 (-8)	88.6 (-8)
10	Y	Y	Post	Post	51.1 (+2)	26.6 (+2)	20.1 (+2)	97.8 (+2)
11	Y	Y	Survey	Survey	39.6 (-21)	20.5 (-21)	15.6 (-21)	75.7 (-21)
SSASA	Y	Y	Post	Pre & Post	50.0	26.1	19.7	95.8
12	Y	Y	Pre & Post, Survey	Pre & Post, Survey	54.5 (+9)	26.3 (+1)	18.9 (-4)	100 (+4)

Spatial complexity makes a difference to SB…but it's complicated and not all models should be considered equally valid/justifiable.

Results - Spatial model reference points

Spatial model gives regional estimate of biomass relative to reference points and that allows managers to make IFQ apportionment decisions based on biological, social, and economic considerations.