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Investigating the effect of abundance based PSC using the multispecies technical interaction model

Kotaro Ono

SSC meeting , April 4th 2016

Context

- Halibut PSC in BSAI is currently fixed, irrespective of halibut stock status
- Moving towards abundance based PSC?
- What would be the consequence to the BSAI groundfish fishery and the directed halibut fishery?

The multispecies technical interaction model

- **Current** model structure:
  - <u>M</u>SE
  - <u>M</u>ultispecies
  - <u>M</u>imics quota allocation
  - <u>M</u>odels fishing dynamics

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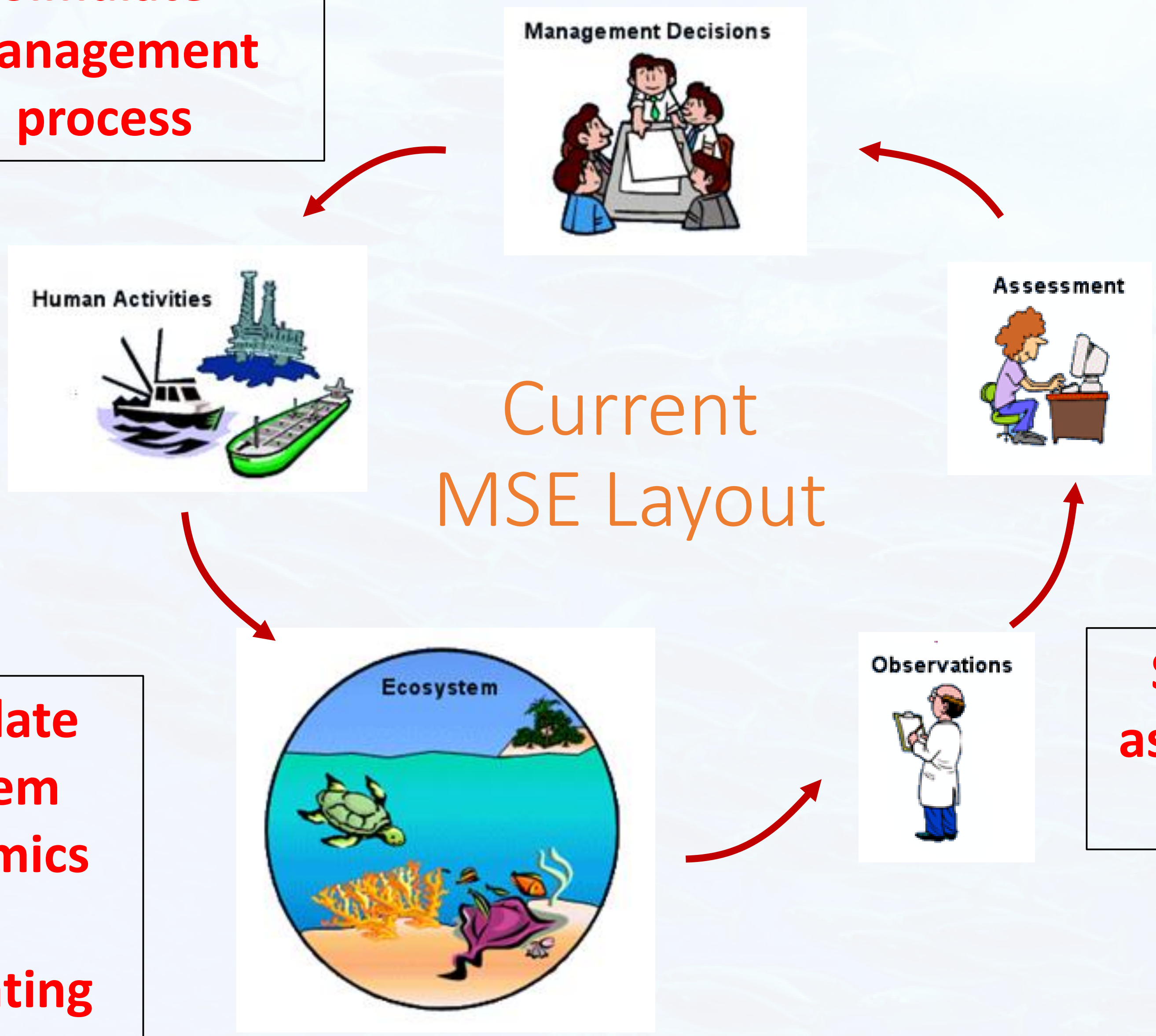
Current MSE Layout

Simulate management process



Simulate assessment process

Simulate System Dynamics = Operating Model

Modified from: CSIRO, Australia

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Simulate
System
Dynamics
=
Operating
Model

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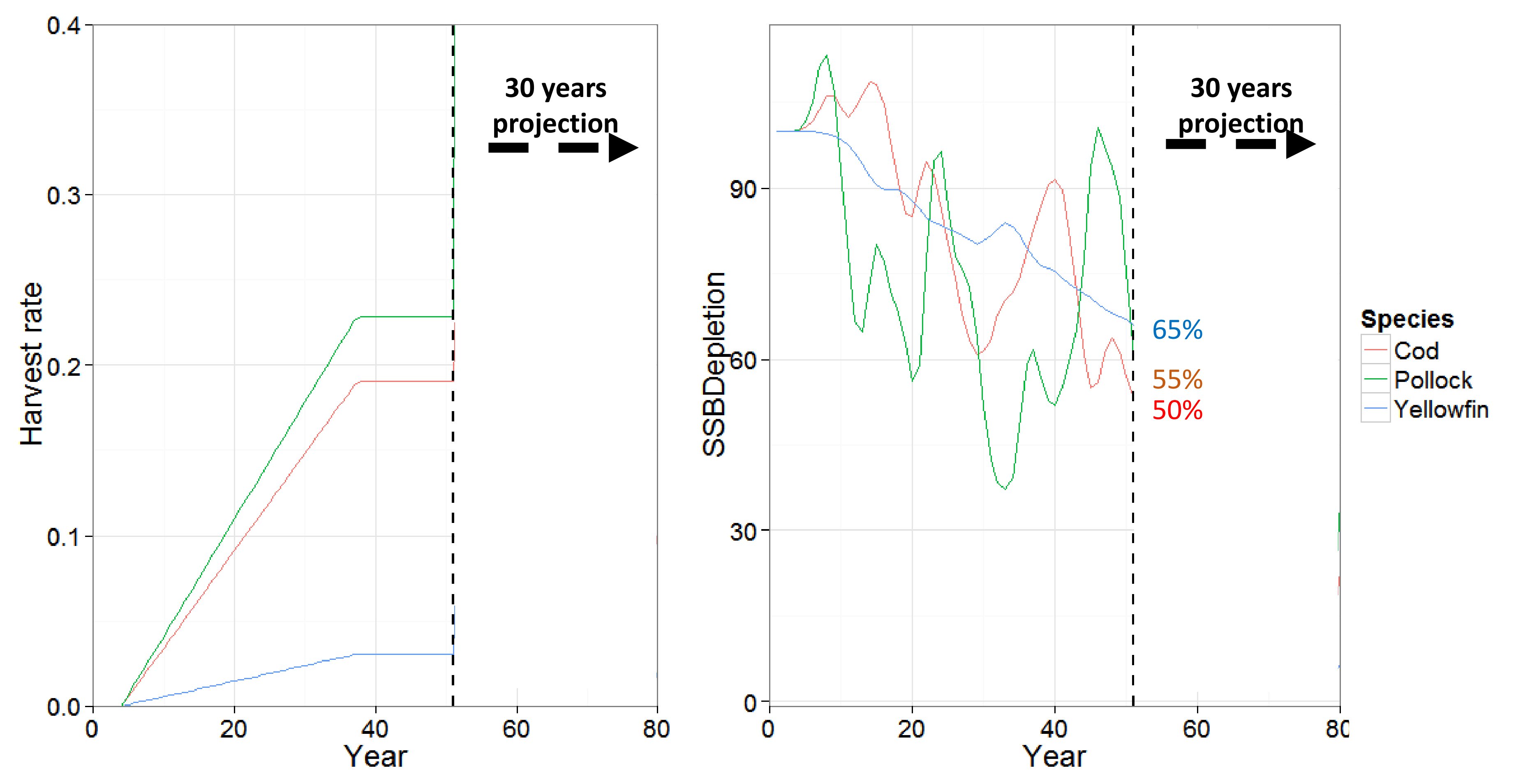
Simulate System Dynamics = Operating Model

The OM

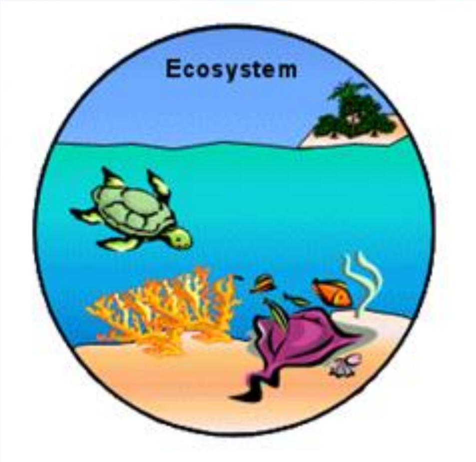
- Age-sex structured, no predator-prey dynamics
  - VB growth
  - Asymptotic age selectivity (1 fishing fleet + 1 survey)
  - BH stock-recruitment relationship
- One way-trip historical fishing trajectory

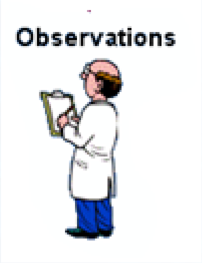
- 3 BSAI species (i.e. cod, pollock, yellowfin sole)
- **Fixed** halibut bycatch limit

The OM


0.4
0.3
0.2
0.1
0.0
Harvest rate
0
20
40
60
80
Year
30 years
projection
90
60
30
0
SSBDepletion
0
20
40
60
80
Year
30 years
projection
65%
55%
50%
Species
Cod
Pollock
Yellowfin

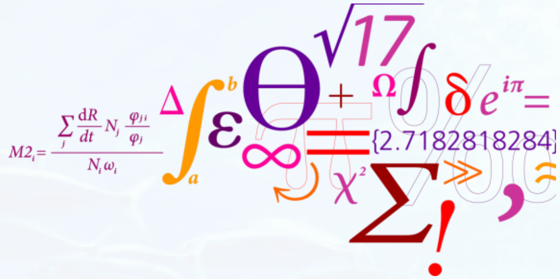
- Index of abundance
- Age composition data



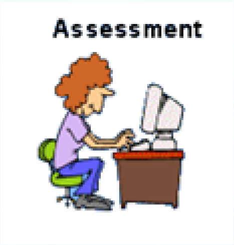


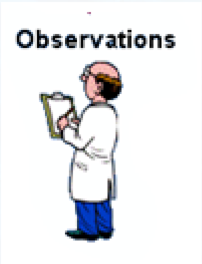
Data generation

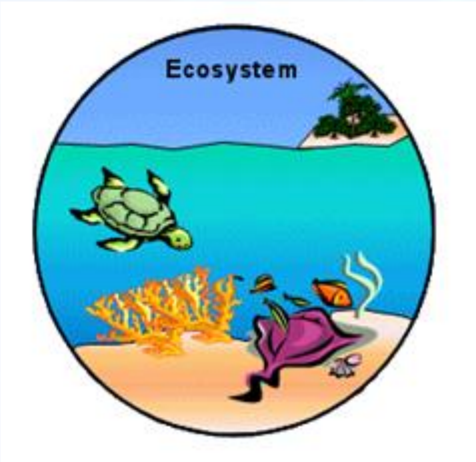
Modified from: CSIRO, Australia



Stock assessment



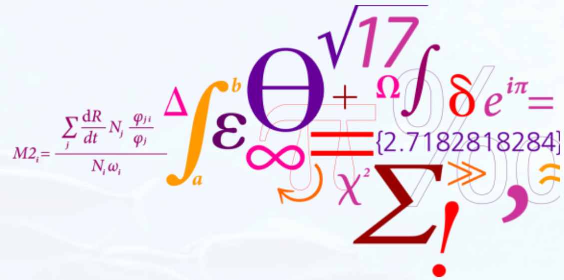




Modified from: CSIRO, Australia

Assessment model

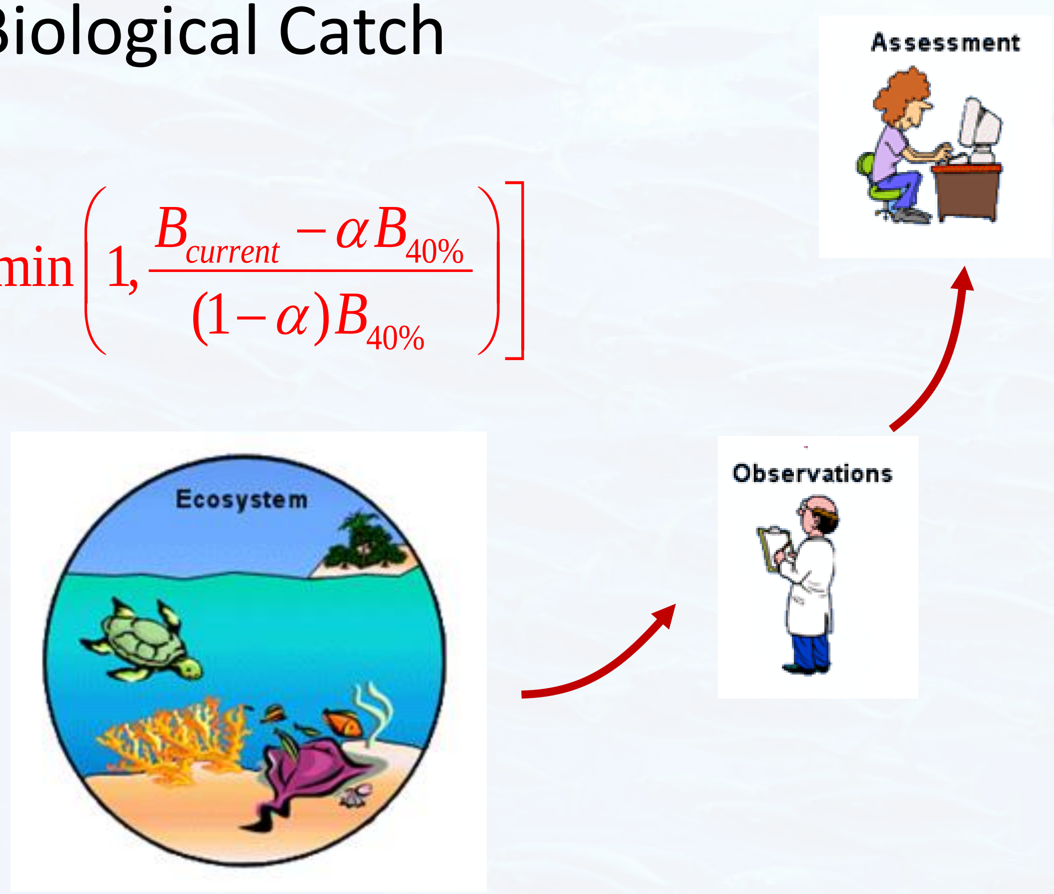
- "CAB" model (Cabezon, Cope et al. 2003)
  - Same structure as the OM
  - Generic, simple, and fast (good for MSE)
  - Estimate: recdevs, selectivity, SSB_0
- Data for assessment:
  - Fishery and survey age composition
  - Survey index of abundance



Stock assessment

- Acceptable Biological Catch (ABC)

$$F_{ABC} = \max\left[0, F_{40\%} \min\left(1, \frac{B_{current} - \alpha B_{40\%}}{(1-\alpha) B_{40\%}}\right)\right]$$



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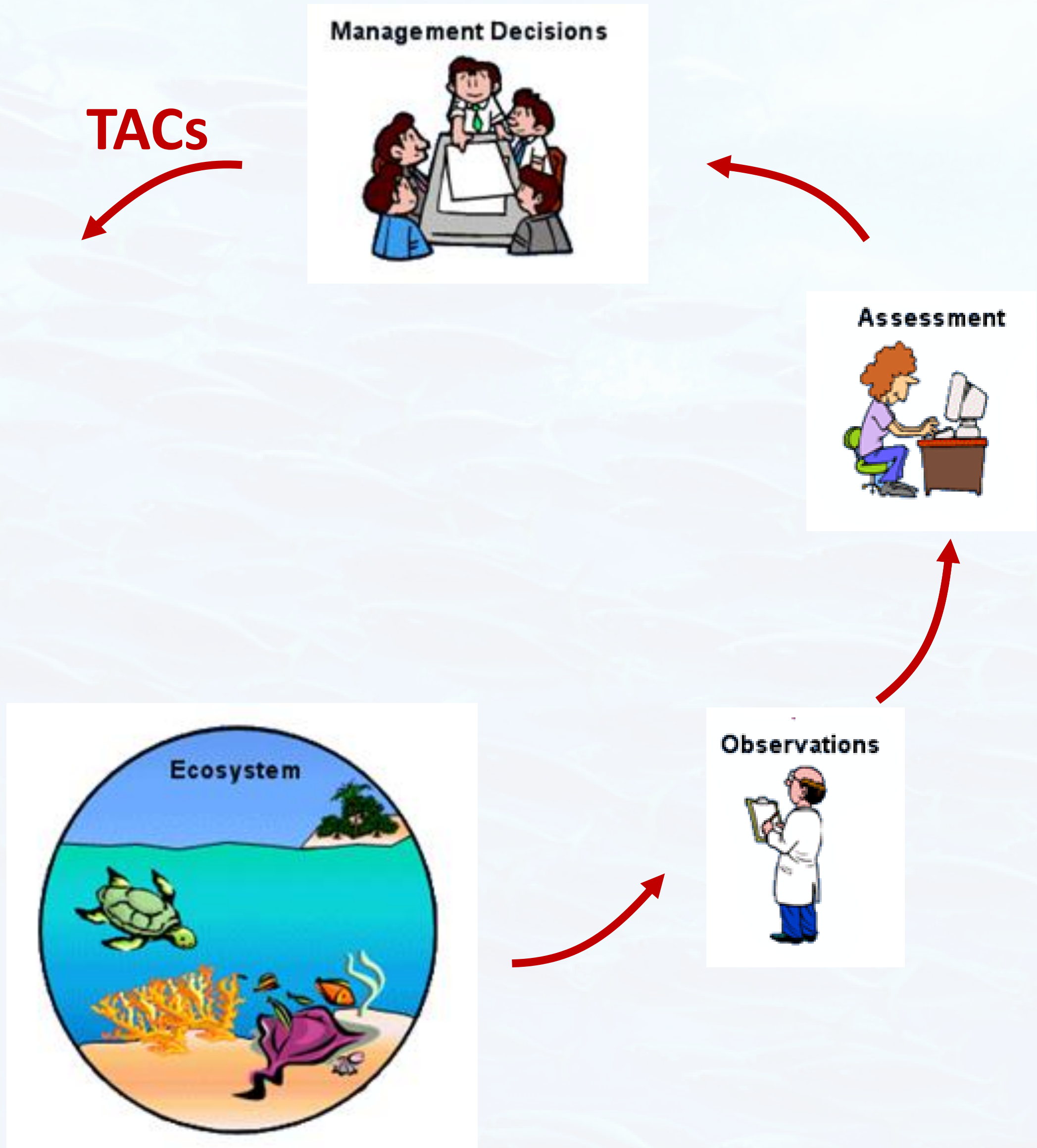
Quota allocation



Modified from: CSIRO, Australia

Quota allocation

- Allocate quota to each species by accounting for:
  - Past fishing pattern
  - Stock assessment recommended Acceptable Biological Catch (ABC)
  - Total yield and bycatch constraints

How to do this?

Through the use of linear programming

Linear programming

Net price

Maximize $$\Theta_{t+1} = \sum_{k=1}^{n_{metier}} \sum_{j=1}^{n_{species}} p_j d_{k,t+1} \frac{C^{obs}_{j,k,t}}{\sum_{k'=1}^{n_{metier}} C^{obs}_{j,k',t}}$$

Red: estimated
Black: input values

Past observed catch composition

Under conservation measures and constraints:

1. $$\sum_{k=1}^{n_{metier}} d_{k,t+1} \frac{C^{obs}_{j,k,t}}{\sum_{k'=1}^{n_{metier}} C^{obs}_{j,k',t}} \le ABC_{j,t+1} \quad \text{for species } j, \ \text{metier } k$$ *"Target species quota constraints"*

2. $$\sum_{k}^{n_{metier}} d_{k,t+1} \frac{C^{obs}_{bycatch,k,t}}{\sum_{k'=1}^{n_{metier}} C^{obs}_{bycatch,k',t}} \le PSC$$ *"Bycatch limit = 4426 (halibut PSC)"*

3. $$\sum_{k=1}^{n_{metier}} \sum_{j=1}^{n_{species}} d_{k,t+1} \frac{C^{obs}_{j,k,t}}{\sum_{k'=1}^{n_{metier}} C^{obs}_{j,k',t}} \le OY$$ *"The OY hard cap"*

4. $$\lambda_1 d_{k,t=1} \le d_{k,t+1} \le \lambda_2 d_{k,t=1}$$ *"Métier concentration factor: contraction (λ_1)/expansion (λ_2)"*

"Dissecting" the fisheries

- "Métier" (Ulrich et al. 2009, Andersen et al. 2011)

= combination of fishing ground, gear and fish assemblages

Method:

- Run *cluster analysis* on observer catch composition data
  - Finds *groups* with *similar catch characteristics*

The data + data processing

- Observer data (NORPAC)
  - 2011-2014
  - BSAI region only
  - Species catch (weight) by operation

- Data processing
  - Define "*sector*" *i.e. A80, Longline CP, CDQ, BSAI TLA* (thanks to Jason Gasper and Josh Keaton)

The data + data processing

- Observer data (NORPAC)
  - 2011-2014
  - BSAI region only
  - Species catch (weight) by operation

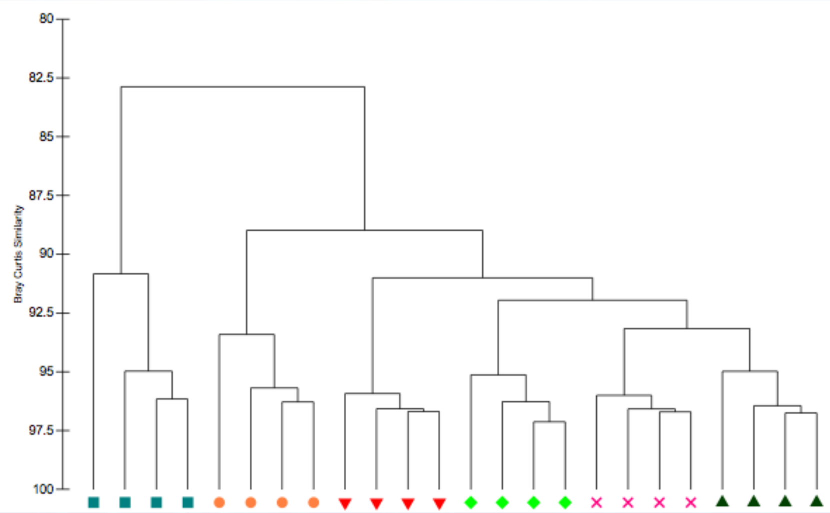
GEAR_TYPE	VESSEL_TYPE	NMFS_AREA	Month_day	Month	YEAR	CDQ_sector	Longline_sector	A80_sector	BSAI_limited_access_sector	ALASKA.PLAICE	ALASKA.SKATE	ALEUTIAN.SCORPIONFISH
1	1	509	2016-01-25	1	2011	0	0	1	0	27.68	210.23	0
1	1	509	2016-01-25	1	2011	0	0	1	0	102.72	1122.17	0
1	1	509	2016-01-25	1	2011	0	0	1	0	59.16	406.26	0
1	1	509	2016-01-26	1	2011	0	0	1	0	182.11	1108.17	0
1	1	509	2016-01-22	1	2011	0	0	1	0	1469.62	364.68	0
1	1	509	2016-01-23	1	2011	0	0	1	0	1719.37	952.96	0

ALEUTIAN.SKATE	ARROWTOOTH.FLOUNDER	ATKA.MACKEREL	AURORA.ROCKFISH	BAIRDI.TANNER.CRAB	BANK.ROCKFISH	BERING.SKATE	BIG.SKATE	BIGMOUTH.SCULPIN	BLACK.ROCKFISH	BLACKFIN.SCULPIN
0	0.00	0	0	0.00	0	0	0	0	0	0
0	0.00	0	0	188.18	0	0	0	0	0	0
0	0.00	0	0	90.13	0	0	0	0	0	0
0	0.00	0	0	126.80	0	0	0	0	0	0
0	329.09	0	0	0.00	0	0	0	0	0	0
0	179.00	0	0	17.02	0	0	0	0	0	0

BLACKGILL.ROCKFISH	BLACKSPOTTED.ROCKFISH	BLOB.SCULPIN	BLUE.ROCKFISH	BOCACCIO.ROCKFISH	BROAD.BANDED.THORNYHEAD	BROWN.IRISH.LORD	BUFFALO.SCULPIN	BUTTERFLY.SKATE
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0

Cluster analysis

- For each sector (4) and area (14):
  - Apply the partitioning around medoids (Kaufman and Rousseeuw 1990) to the tow by tow species (113) raw catch data (across 2011-2014)
  - Divide into 2-10 clusters
  - Choose the best number of clusters i.e. the one that maximizes the silhouette index (Cope et al. 2009)
  - Keep the results for the 4 species of interest



Fishing patterns by month, area, sector

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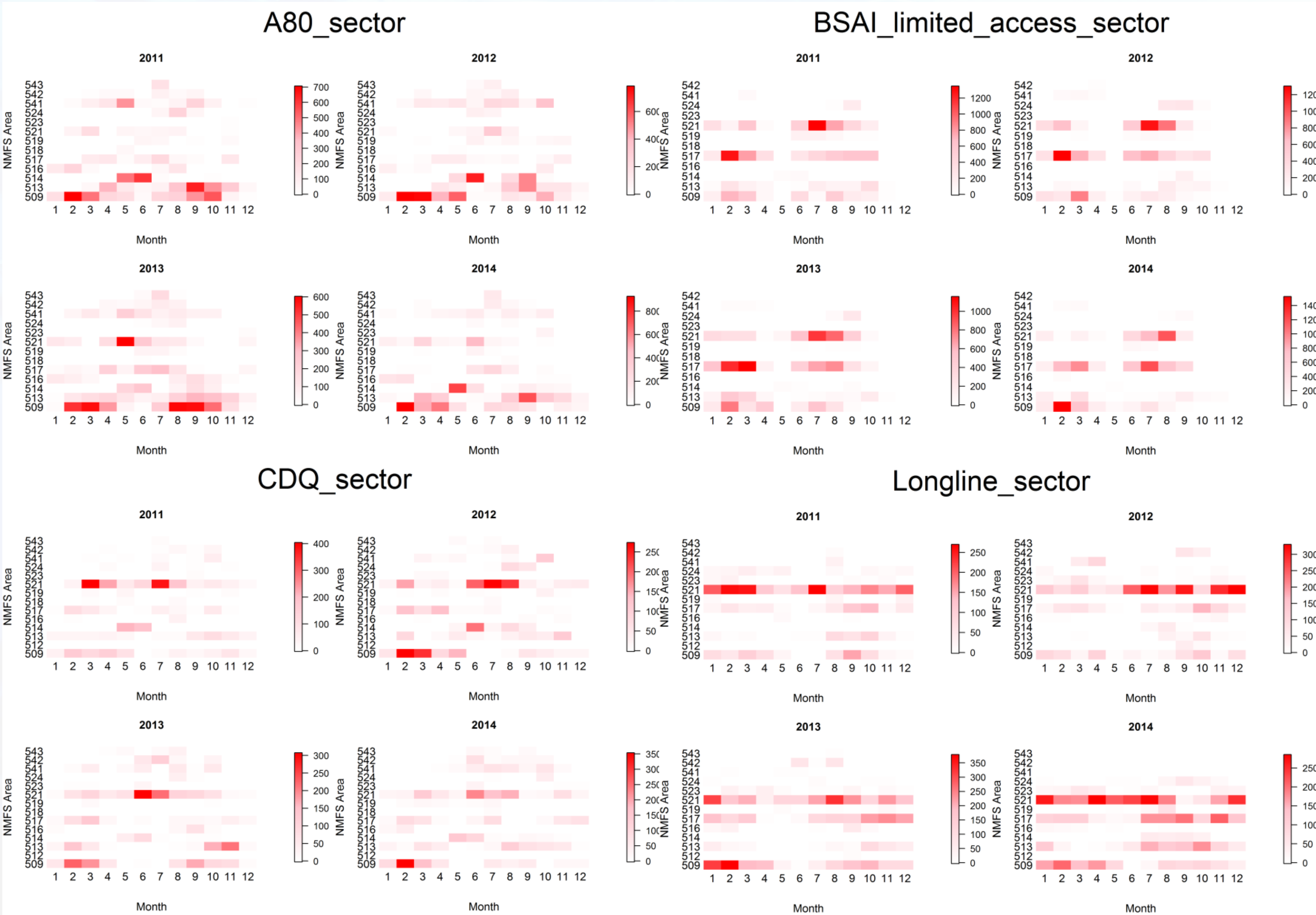

Cluster analysis output

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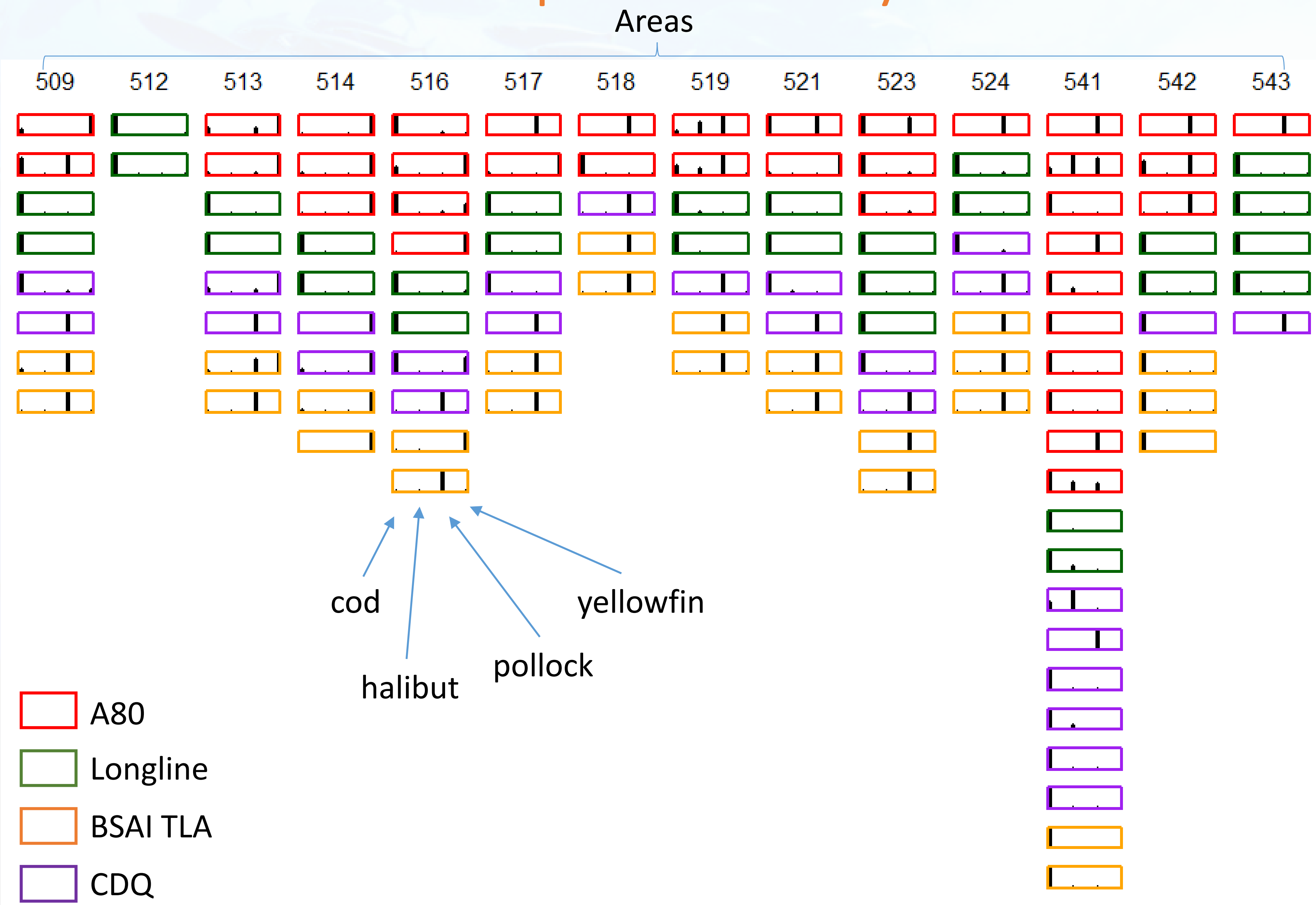
Catch composition by métiers



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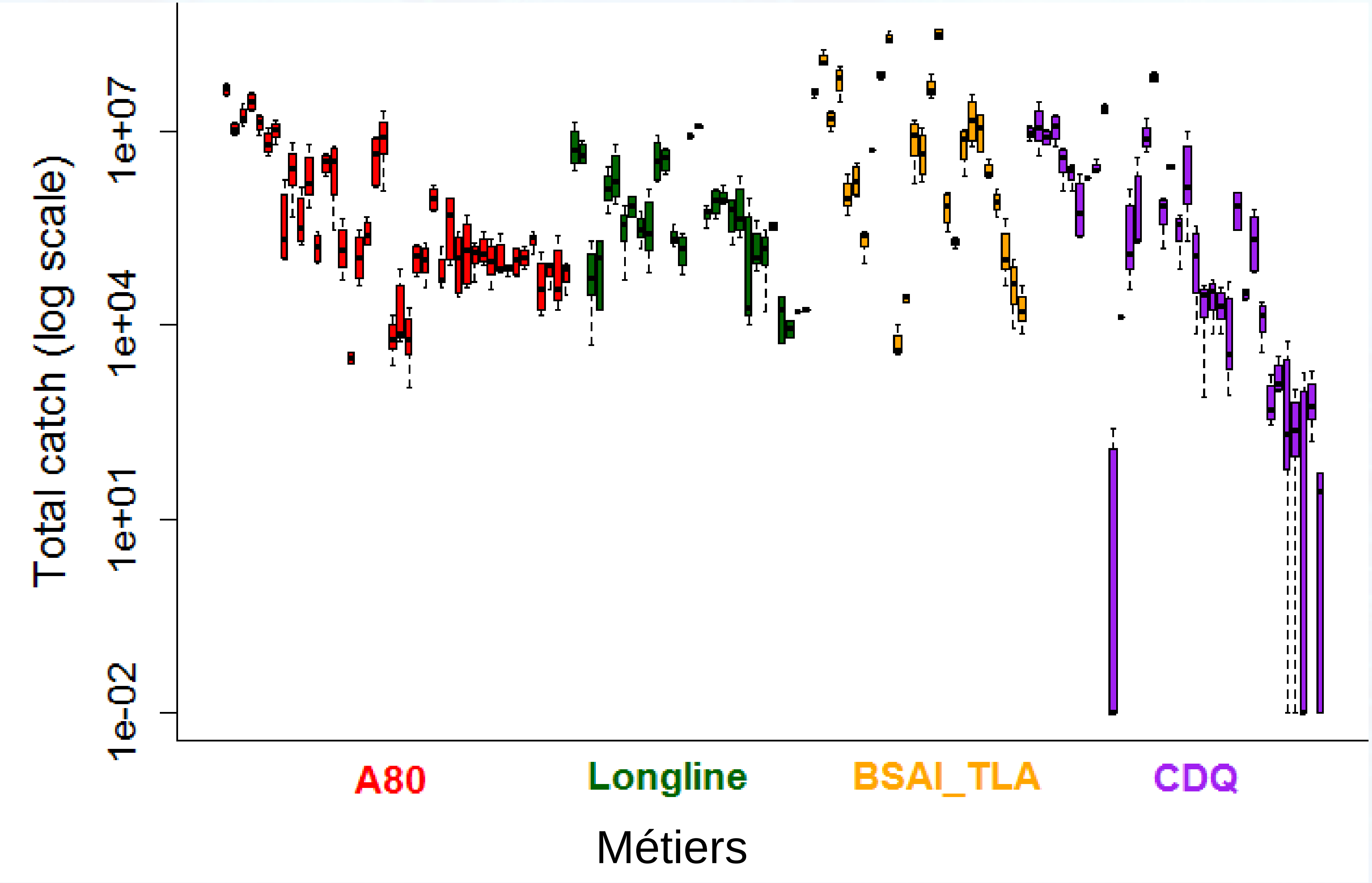
Variability in between-year catch within "métiers"



Linear programming

Net price

Maximize $$\Theta_{t+1} = \sum_{k=1}^{n_{metier}} \sum_{j=1}^{n_{species}} p_j d_{k,t+1} \frac{C^{obs}_{j,k,t}}{\sum_{k'=1}^{n_{metier}} C^{obs}_{j,k',t}}$$

Red: estimated
Black: input values

Past observed catch composition

Under conservation measures and constraints:

1. $\sum_{k=1}^{n_{metier}} d_{k,t+1} \frac{C^{obs}_{j,k,t}}{\sum_{k'=1}^{n_{metier}} C^{obs}_{j,k',t}} \leq ABC_{j,t+1}$ for species j, metier k — *"Target species quota constraints"*

2. $\sum_{k}^{n_{metier}} d_{k,t+1} \frac{C^{obs}_{bycatch,k,t}}{\sum_{k'=1}^{n_{metier}} C^{obs}_{bycatch,k',t}} \leq PSC$ — *"Bycatch limit = 4426 (halibut PSC)"*

3. $\sum_{k=1}^{n_{metier}} \sum_{j=1}^{n_{species}} d_{k,t+1} \frac{C^{obs}_{j,k,t}}{\sum_{k'=1}^{n_{metier}} C^{obs}_{j,k',t}} \leq OY$ — *"The OY hard cap = $2e^6$"*

4. $\lambda_1 d_{k,t=1} \leq d_{k,t+1} \leq \lambda_2 d_{k,t=1}$ — *"Métier concentration factor: contraction (λ_1)/expansion (λ_2)"*

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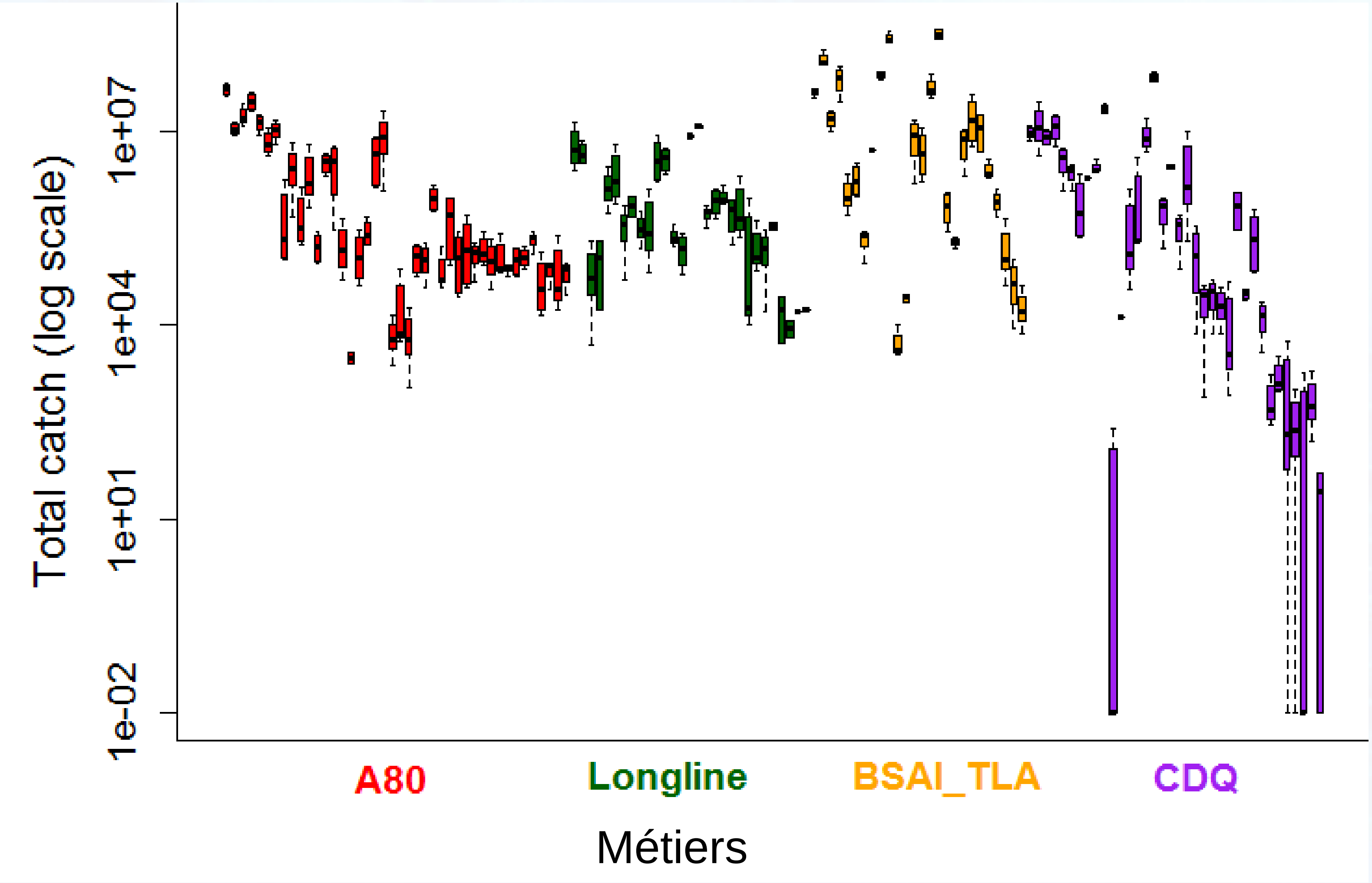

Linear programming

Net price ?

Maximize $$\Theta_{t+1} = \sum_{k=1}^{n_{metier}} \sum_{j=1}^{n_{species}} p_j d_{k,t+1} \frac{C^{obs}_{j,k,t}}{\sum_{k'=1}^{n_{metier}} C^{obs}_{j,k',t}}$$

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Black: input values

Past observed catch composition

Under conservation measures and constraints:

1. $$\sum_{k=1}^{n_{metier}} d_{k,t+1} \frac{C^{obs}_{j,k,t}}{\sum_{k'=1}^{n_{metier}} C^{obs}_{j,k',t}} \leq ABC_{j,t+1} \quad \text{for species } j, \text{ metier } k$$
"Target species quota constraints"

2. $$\sum_{k}^{n_{metier}} d_{k,t+1} \frac{C^{obs}_{bycatch,k,t}}{\sum_{k'=1}^{n_{metier}} C^{obs}_{bycatch,k',t}} \leq PSC$$
"Bycatch limit = 4426 (halibut PSC)"

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"The OY hard cap = $2e^6$"

4. $$\lambda_1 d_{k,t=1} \leq d_{k,t+1} \leq \lambda_2 d_{k,t=1}$$
"Métier concentration factor: contraction (λ_1)/expansion (λ_2)"

"Adjusting" the net price in the MSE

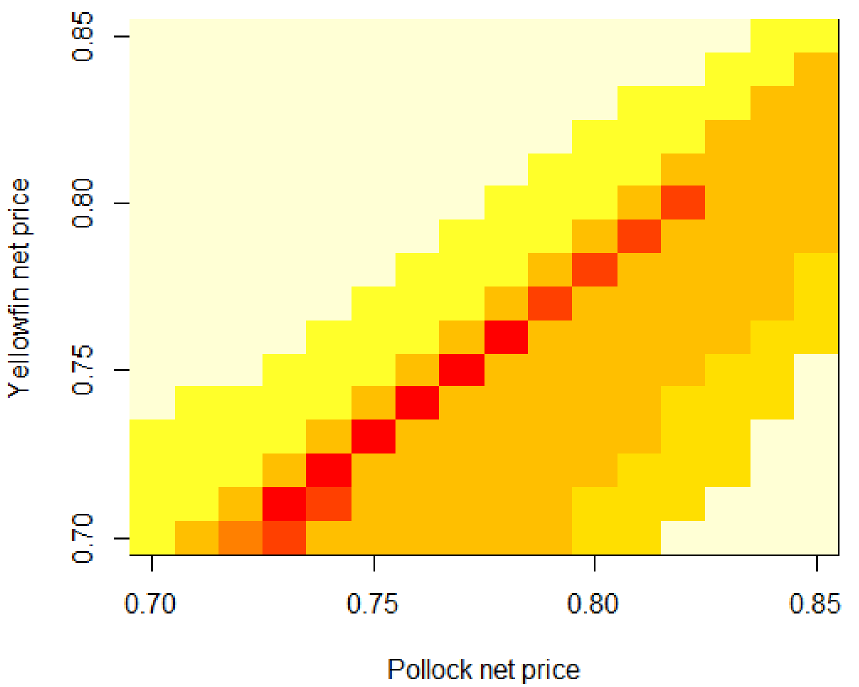
→ *To mimic the quota allocation (or species' catch+bycatch)*

BSAI harvest specifications from 1986 - present

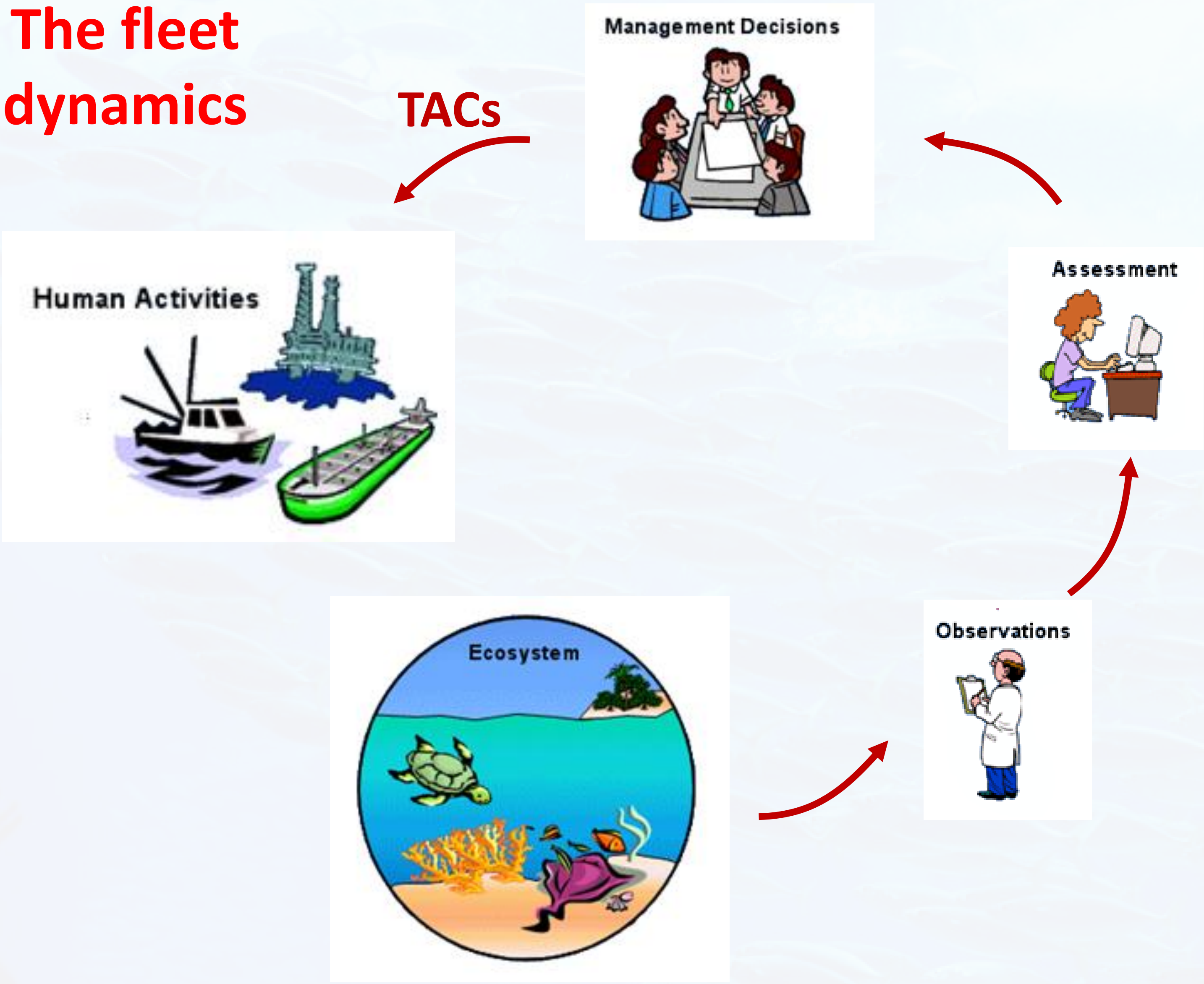
Species	Area	2015 OFL	ABC	TAC	iTAC	CDQ	OF
Pollock	BS	3,330,000	1,637,000	1,310,000	1,179,000	131,000	2,795
	AI	36,005	29,659	19,000	17,100	1,900	42
	Bogslof	21,200	15,900	100	100	0	13
Pacific cod	BSAI						
	BS	346,000	255,000	240,000	214,320	25,680	299
	AI	23,400	17,600	9,422	8,414	1,008	20
Sablefish	BSAI Total						
	BS	1,575	1,333	1,333	567	183	1
	AI	2,128	1,802	1,802	383	304	2
Yellowfin Sole	BSAI	266,400	248,800	149,000	133,057	15,943	259

$$\text{minimize}\left[\sum_{k}^{n_{species}}\left(observed - predicted_{\text{model}}\right)^2\right]$$

Cod = 1.0 (fixed)
Pollock= 0.73
Yellowfin sole = 0.71
Halibut = 0



The fleet dynamics



Modified from: CSIRO, Australia

How to determine the realized catch? The fleet dynamics

- Hyp: fleets maximize same utility function
- BUT EVERY year
  - Catch composition by métiers changes wrt species abundance

$$C_{j,k,t+1}^{obs} = C_{j,k,t}^{obs} \frac{B_{j,t+1}}{B_{j,ref}}$$

→ Creates mismatch between realized catch *vs.* allocated quota

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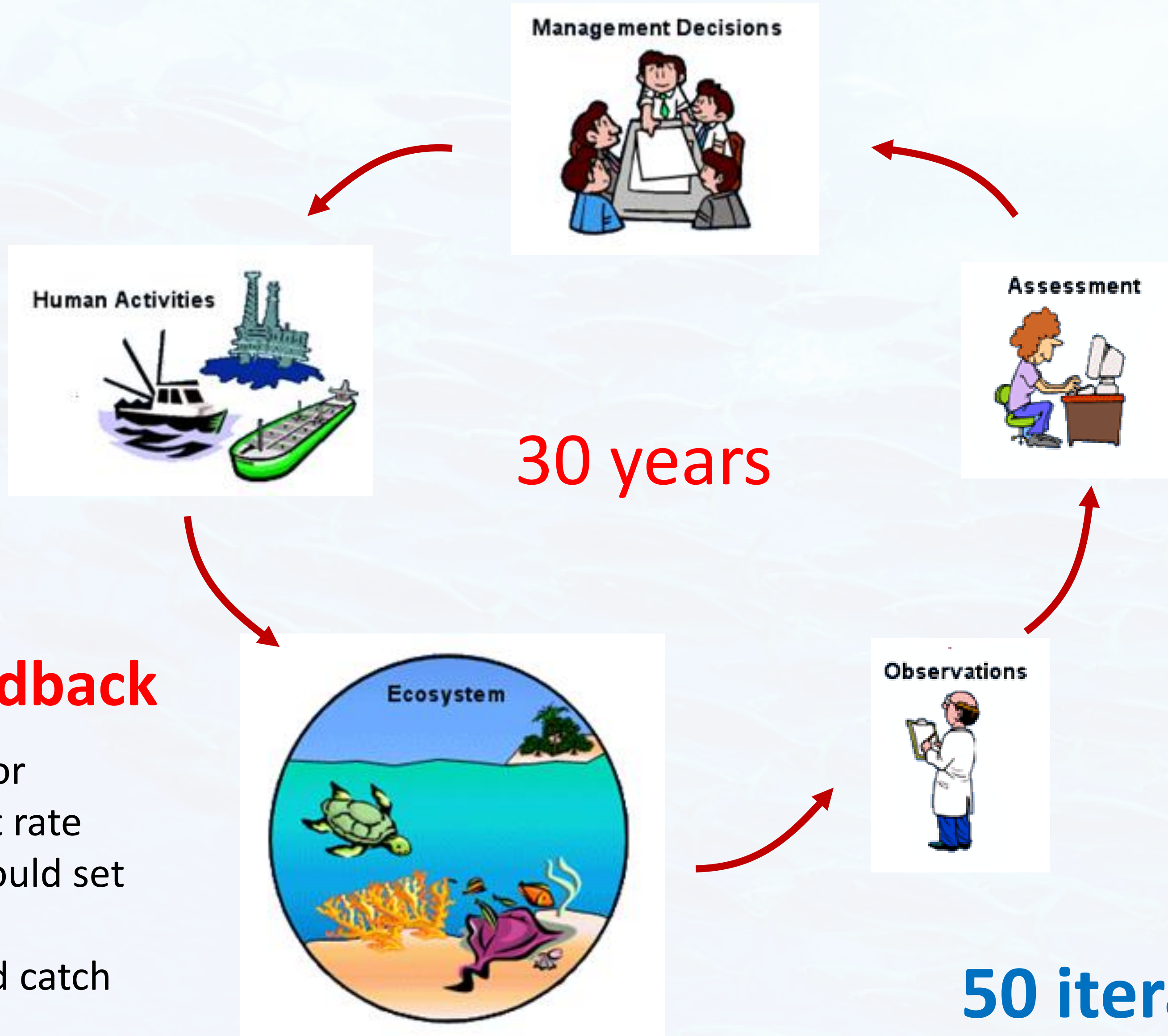

Feedback

Solve for harvest rate that would set catch = realized catch

50 iterations

Modified from: CSIRO, Australia

Things we can examine

Scenario example:

- Potential consequence of halibut bycatch reduction?

- Fixed vs. abundance based PSC?

Effect of halibut bycatch reduction

To come…

will be updated by SSC meeting

Moving on to the abundance based halibut PSC case study

- Include more BSAI groundfish species

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Species	Area	2015					2014				
		OFL	ABC	TAC	iTAC	CDQ	OFL	ABC	TAC	iTAC	CDQ
Pollock	BS	3,330,000	1,637,000	1,310,000	1,179,000	131,000	2,795,000	1,369,000	1,267,000	1,140,300	126,700
	AI	36,005	29,659	19,000	17,100	1,900	42,811	35,048	19,000	17,100	1,900
	Bogslof	21,200	15,900	100	100	0	13,413	10,059	75	75	0
Pacific cod	BSAI										
	BS	346,000	255,000	240,000	214,320	25,680	299,000	255,000	246,897	220,479	26,418
	AI	23,400	17,600	9,422	8,414	1,008	20,100	15,100	6,997	6,248	749
Sablefish	BSAI Total										
	BS	1,575	1,333	1,333	567	183	1,584	1,339	1,339	1,105	184
	AI	2,128	1,802	1,802	383	304	2,141	1,811	1,811	1,471	306
Yellowfin Sole	BSAI	266,400	248,800	149,000	133,057	15,943	259,700	239,800	184,000	164,312	19,688
Greenland Turbot	BSAI	3,903	3,172	2,648	2,251	n/a	2,647	2,124	2,124	1,805	n/a
	BS	n/a	2,448	2,448	2,081	262	n/a	1,659	1,659	1,410	178
	AI	n/a	724	200	170	0	n/a	465	465	395	0
Arrowtooth Flounder	BSAI	93,856	80,547	22,000	18,700	2,354	125,642	106,599	25,000	21,250	2,675
Kamchatka Flounder	BSAI	10,500	9,000	6,500	5,525	0	8,270	7,100	7,100	6,035	0
Rock Sole	BSAI	187,600	181,700	69,250	61,840	7,410	228,700	203,800	85,000	75,905	9,095
Flathead Sole	BSAI	79,419	66,130	24,250	21,655	2,595	79,633	66,293	24,500	21,879	2,622
Alaska Plaice	BSAI	54,000	44,900	18,500	15,725	0	66,800	55,100	24,500	20,825	0
Other Flatfish	BSAI	17,700	13,250	3,620	3,077	0	16,700	12,400	2,650	2,253	0
Pacific Ocean Perch	BSAI	42,558	34,988	32,021	28,250	n/a	39,585	33,122	33,122	29,248	n/a
	BS	n/a	8,771	8,021	6,818	0	n/a	7,684	7,684	6,531	0
	AI Total										
	EAI	n/a	8,312	8,000	7,144	856	n/a	9,246	9,246	8,257	989
	CAI	n/a	7,723	7,000	6,251	749	n/a	6,594	6,594	5,888	706
	WAI	n/a	10,182	9,000	8,037	963	n/a	9,598	9,598	8,571	1,027
Sharpchin/Northern Rockfish	BSAI										
	BS										
	AI										
Northern Rockfish	BSAI	15,337	12,488	3,250	2,763	0	12,077	9,761	2,594	2,205	0
	BS										
	AI										
Rougheye Rockfish	BSAI	560	453	349	297	0	505	416	416	354	0
	EBS/EAI	n/a	149	149	127	0	n/a	177	177	150	0
	CAI/WAI	n/a	304	200	170	0	n/a	239	239	203	0
Shortraker Rockfish	BSAI	690	518	250	213	0	493	370	370	315	0
Shortraker/Rougheye Rockfish	BSAI										
	BS										
	AI										
Other Red Rockfish	BS										
	AI										
Other Rockfish	BSAI	1,667	1,250	880	748	0	1,550	1,163	773	657	0
	BS	n/a	695	325	276	0	n/a	690	300	255	0
	AI	n/a	555	555	472	0	n/a	473	473	402	0
Atka Mackerel	BSAI	125,297	106,000	54,500	48,669	5,832	74,492	64,131	32,322	28,863	3,458
	EAI/BS	n/a	38,492	27,000	24,111	2,889	n/a	21,652	21,652	19,335	2,317

Including halibut in the OM

One approach

- Based on CAB fit to IPHC estimates of SSB and proportion at age (coastwide model)
- project recruitment deviation in the future (e.g. from fitting a time series model to IPHC estimate of rec-devs)

Mimicking directed halibut fishery

- Use historical global fishing rates

E.g., in future year t let

$$F_t = f\left(B_t\right) + \varepsilon_t, \qquad \varepsilon_t = N\left(0, \sigma_F^2\right)$$

where $f\left(B_t\right)$ and associated variability would be determined based on some historical period.

- Option could also include current IPHC over-arching 30-20 rule

KEY POINT: PSC analysis would not pre-suppose future IPHC MSE feedback and/or future developments…

BCR options for halibut PSC in BSAI

- From discussion paper (see attachment 1 e.g.)
- Candidate BCRs should consider
  - Data generation needs from operating model
  - Which abundance indices to use and how to simulate; e.g.,
    - ✓ Adult index = based on SSB in the OM
    - ✓ Recruitment index (BSAI) = need to find relationship with historical halibut abundance; e.g.,

$$IA_t^{recruit} = g\left(B_t\right) + \varepsilon_t, \quad \varepsilon_t = N\left(0, \sigma_{IA}^2\right)$$

Then use it to generate it from the OM

Thank you!

Acknowledgment

NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
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“Adjusting” the net price in the MSE

--> To mimic the 2015 catch+bycatch

X	Pollock, AFA Inshore	570,885	572,197	1,312	100%
X	Pollock, AFA Catcher Processor	457,648	457,758	110	100%
X	Pollock, AFA Mothership	114,388	114,439	51	100%
X	Pollock CDQ	132,858	132,900	42	100%
	Pollock, Incidental Catch, non-Bogoslof (includes CDQ)	45,802	47,160	1,358	97%
	Pollock, Incidental Catch, Bogoslof (includes CDQ)	733	100	-633	733%
X	Pacific Cod, Catcher Processor (AFA)	3,585	3,823	238	94%
X	Pacific Cod, Catcher Processor (Amendment 80)	27,174	32,216	5,042	84%
X	Pacific Cod, Catcher Vessel (Trawl)	37,595	37,854	259	99%
X	Pacific Cod, Catcher Processor (Hook-and-Line)	114,202	115,371	1,169	99%
X	Pacific Cod, Catcher Vessel (Hook-and-Line >= 60 ft)	0	20	20	0%
X	Pacific Cod, Catcher Processor (Pot)	6,180	6,829	649	90%
X	Pacific Cod, Catcher Vessel (Pot >= 60 ft)	10,414	13,641	3,227	76%
X	Pacific Cod (Jig)	28	100	72	28%
	Pacific Cod (Hook-and-Line and Pot < 60 ft)	10,050	12,380	2,330	81%
	Pacific Cod, Incidental Catch (Hook-and-Line and Pot)	271	500	229	54%

$$\text{minimize}\left[\sum_{k}^{n_{species}}\left(observed - predicted_{\text{model}}\right)^2\right]$$

Cod = 1.0 (fixed)
Pollock= 0.73
Yellowfin sole = 0.71
Halibut = 0