F_{MSY} ranges in a multispecies environment

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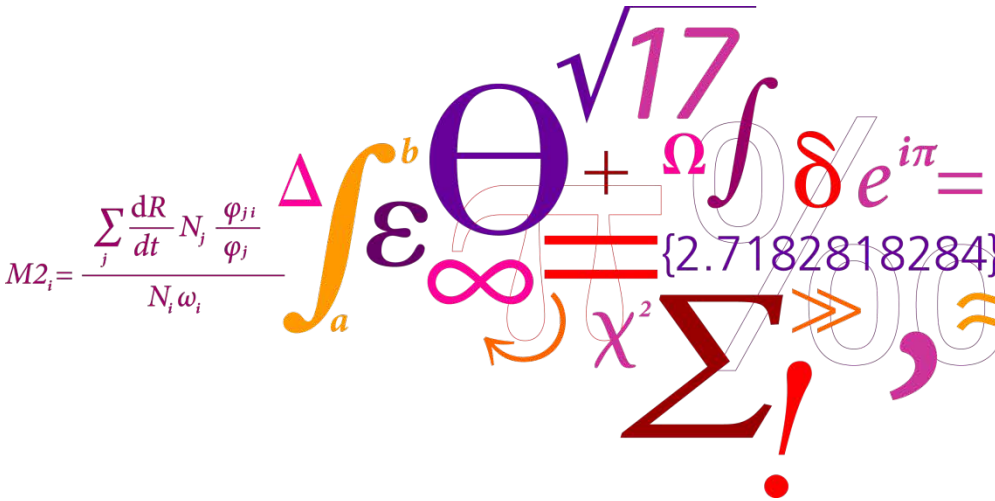

DTU Aqua
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Multispecies environment?

- Model: Stochastic Multi-Species model (SMS)
  - Stock assessment model with estimation of **predation**
    - Input: Catch at age, mean weight at age, proportion mature CPUE …..
    - Input: Diet data from 250.000 fish stomachs
    - Parameter estimation from maximum likelihood

- ”key run” by ICES Working Group on Multispecies Assessment Methods (*WGSAM, 2014*)

North Sea
Stochastic Multi-Species model (SMS)

"Dynamic stocks"

- Cod
- Haddock
- Whiting
- Saithe
- Sprat
- Northern sandeel
- Southern sandeel
- Herring
- Norway pout
- Sprat
- Plaice
- Sole

Fixed predator stocks

- Mackerel
- Horse mackerel
- Grey gurnard
- Starry ray
- Hake
- 9 species of seabirds
- Grey seal
- Harbour porpoise

Objectives, MSY and MSFD in a multispecies context

- Maximum Sustainable Yield or value, by species or total
- Healthy (large) stocks, e.g. MSFD descriptor 3 and 4
- …

First approach: F_{MSY} from maximizing total yield or value

- Make forecast scenarios to equilibrium
  - Mean weight, proportion mature etc. from 10 years average
  - Recruitment from fitted Stock recruitment relations
  - Fix population of other predators (recent 5 years average)

- Use maximization to identify a combination of F's that provides MSY
  - Objective function: Sum of species yield or total landings value
  - Constraints: F <= Fpa
  - Penalty functions: SSB below minimum biomass (e.g. Blim, or Bpa)

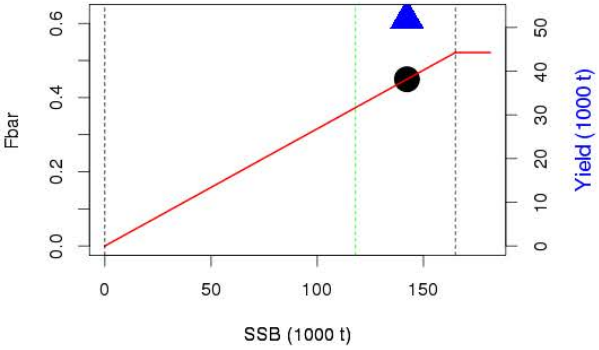
Reference points estimated by ICES (and me)

Stock	B_{lim} (kt)	B_{pa} (kt)	MSY $B_{trigger}$ (kt)	Fpa
Cod	118^	165	165	(0.60)
Whiting	(122^^)	(170)	(170)	(0.15*)
Haddock	63	88	88	(0.60)
Saithe	106	200	200	0.40
Herring	800	1000	(1000)	(0.50)
North sandeel	(200)	(280)	(280	(0.6)
South sandeel	(175)	(245)	(245)	(0.6)
Norway pout	90	150	150 kt	(0.6)
Sprat	90	142	142 kt	(0.7)

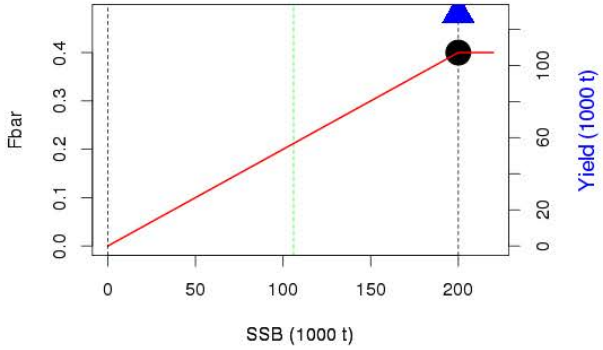
* F used in EU–Norway management strategy ,
^ ICES uses SSB in 1996 (118kt). SSB(1996) as estimated by SMS is 106 kt.
^^ ICES uses Bloss (SSB in 2007, 184 kt, in the 2013 assessment), SSB (2007) as estimated by SMS is 122 kt

Determenistic recruitment, penalize SSB below Blim, maximising total yield, Years: 2024-2063

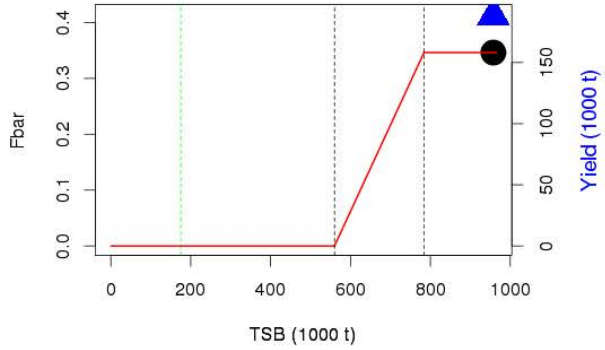
Cod: Median Yield: 52 kt SSB: 142 kt
Target F:0.52



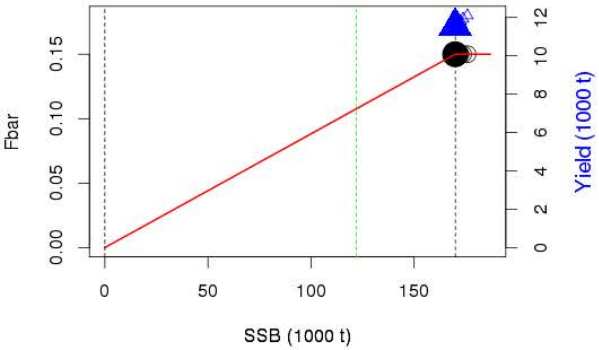
Saithe: Median Yield: 129 kt SSB: 200 kt
Target F:0.40



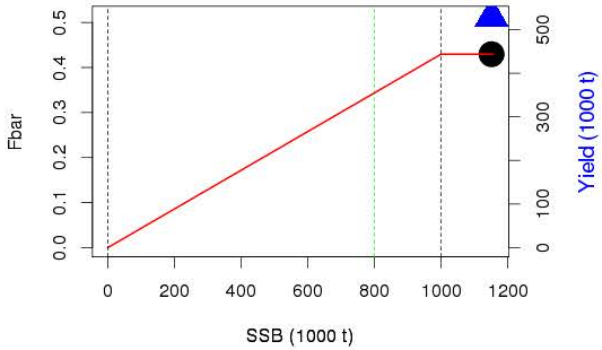
S. sandeel: Median Yield: 188 kt TSB: 958 kt
Target F:0.35



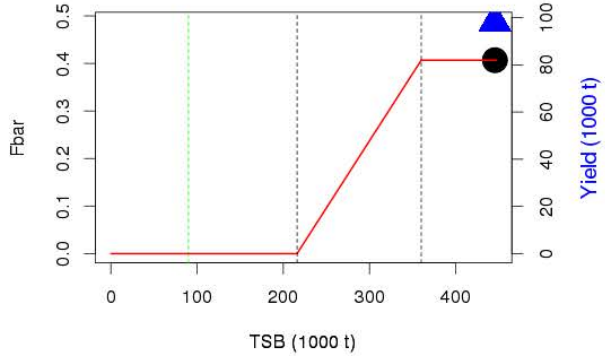
Whiting: Median Yield: 12 kt SSB: 170 kt
Target F:0.15



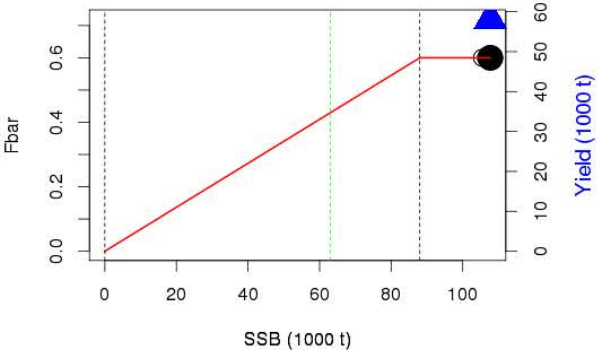
Herring: Median Yield: 530 kt SSB: 1152 kt
Target F:0.43



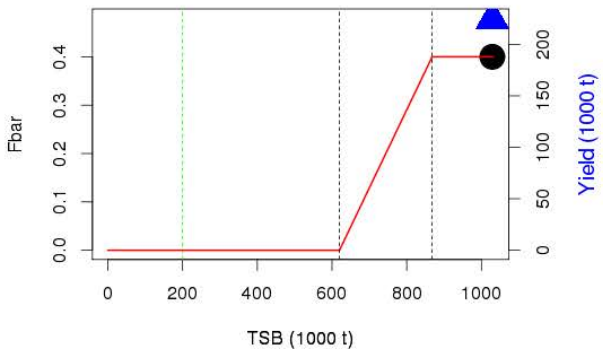
Nor. pout: Median Yield: 98 kt TSB: 445 kt
Target F:0.41



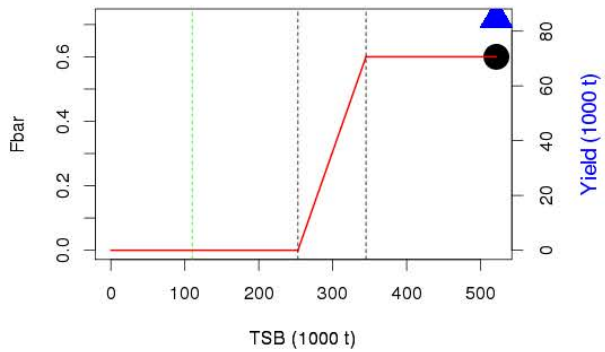
Haddock: Median Yield: 58 kt SSB: 108 kt
Target F:0.60



N. sandeel: Median Yield: 225 kt TSB: 1029 kt
Target F:0.40



Sprat: Median Yield: 85 kt TSB: 521 kt
Target F:0.60



Optimization results, Species F_{MSY}

	Maximize Value		Maximize Yield	
	penalize SSB<Blim	penalize SSB<Bpa	penalize SSB<Blim	penalize SSB<Bpa
1. Cod	0.48	0.34	0.45	0.35
2. Whiting	0.15	0.15	0.15	0.14
3. Haddock	0.60	0.58	0.60	0.60
4. Saithe	0.40	0.38	0.40	0.40
5. Herring	0.40	0.33	0.43	0.37
6. N. sandeel	0.40	0.40	0.40	0.40
7. S. sandeel	0.26	0.17	0.35	0.29
8. Norway pout	0.25	0.15	0.41	0.36
9. Sprat	0.60	0.10	0.60	0.60

Second approach: Identify ”pretty good yield” from graphical output of yield from all combinations of species F

- Make predictions to equilibrium for “all” combinations of potential F_{MSY}
  - “all” combinations of potential F_{MSY}
    - Max species F_{MSY}: F_{PA} or F_{CAP} (or any other ”reasonable” value)
    - Min species F_{MSY}: ~one third of max F

- Visualise the results, for an informed decision on trade-offs

Yield

Cod

Whiting

Haddock

Saithe

Herring

Northern Sandeel

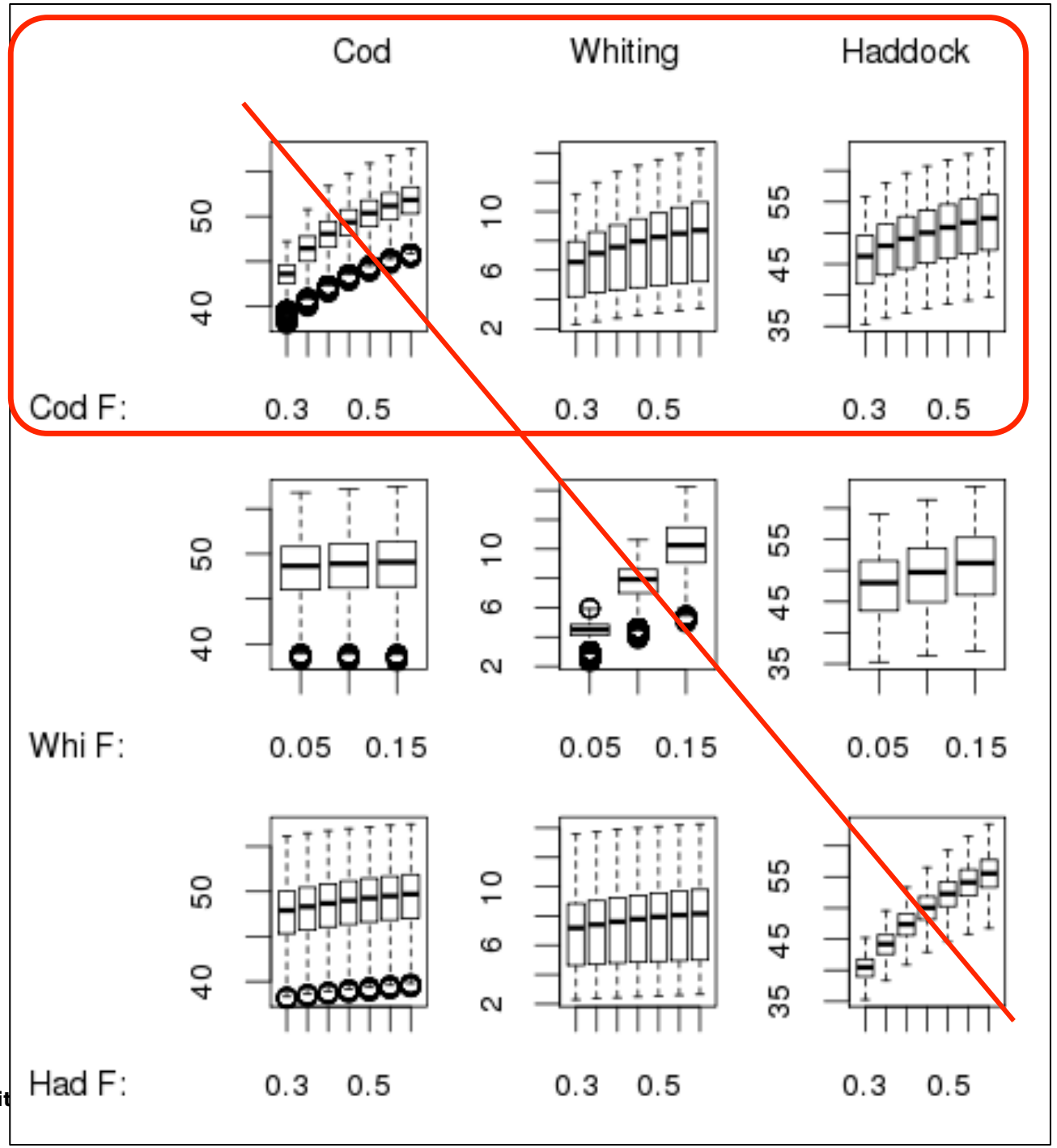
Southern Sandeel

Norway pout

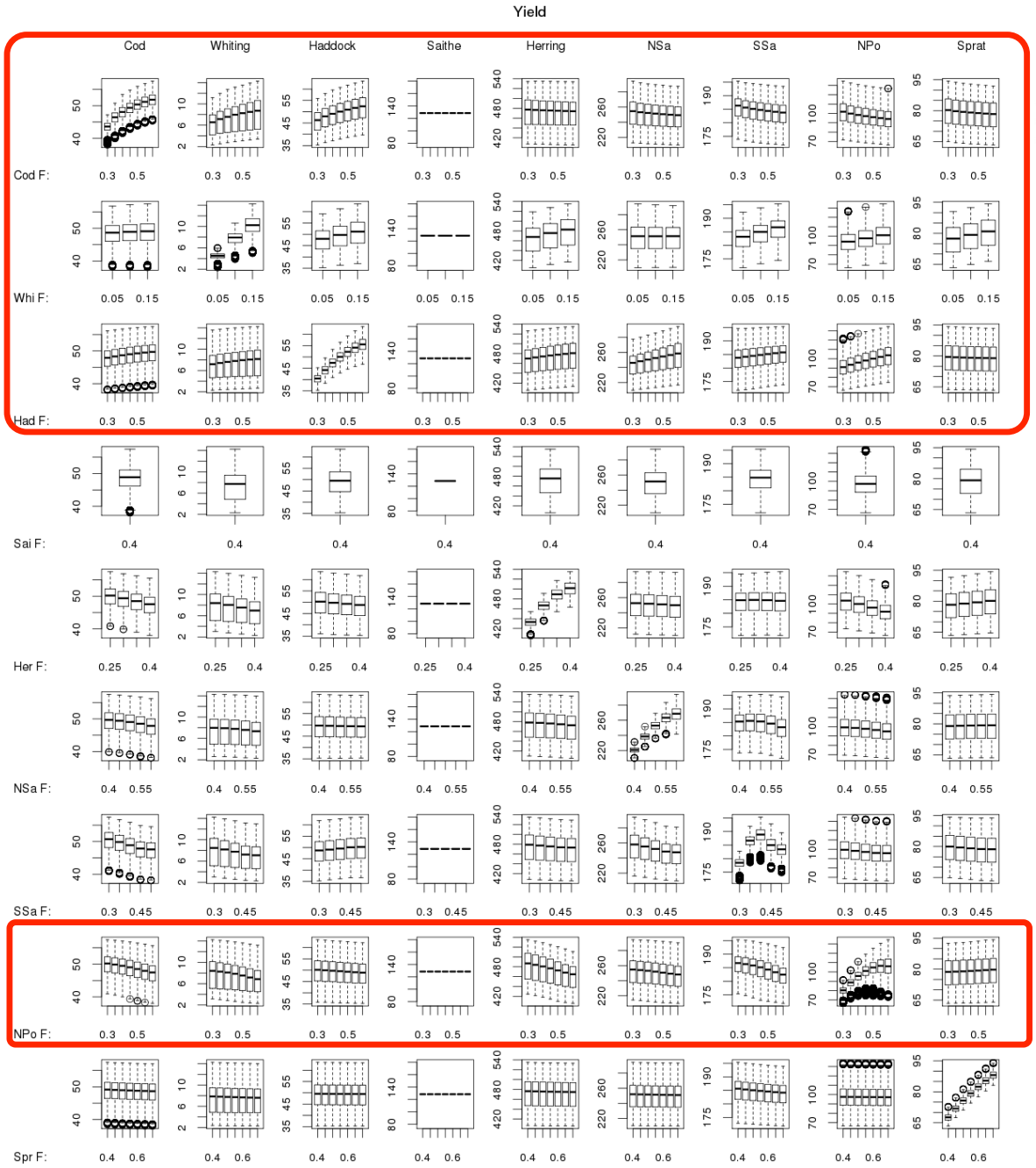
Sprat

Yield (kt)

Species	Min F	Max F
Cod	0.30	0.60
Whiting	0.05	0.15
Haddock	0.30	0.60
Saithe	0.35	0.40
Herring	0.25	0.40
Northern sandeel	0.40	0.60
Southern sandeel	0.30	0.50
Norway pout	0.30	0.60
Sprat	0.40	0.70



Yield by species F

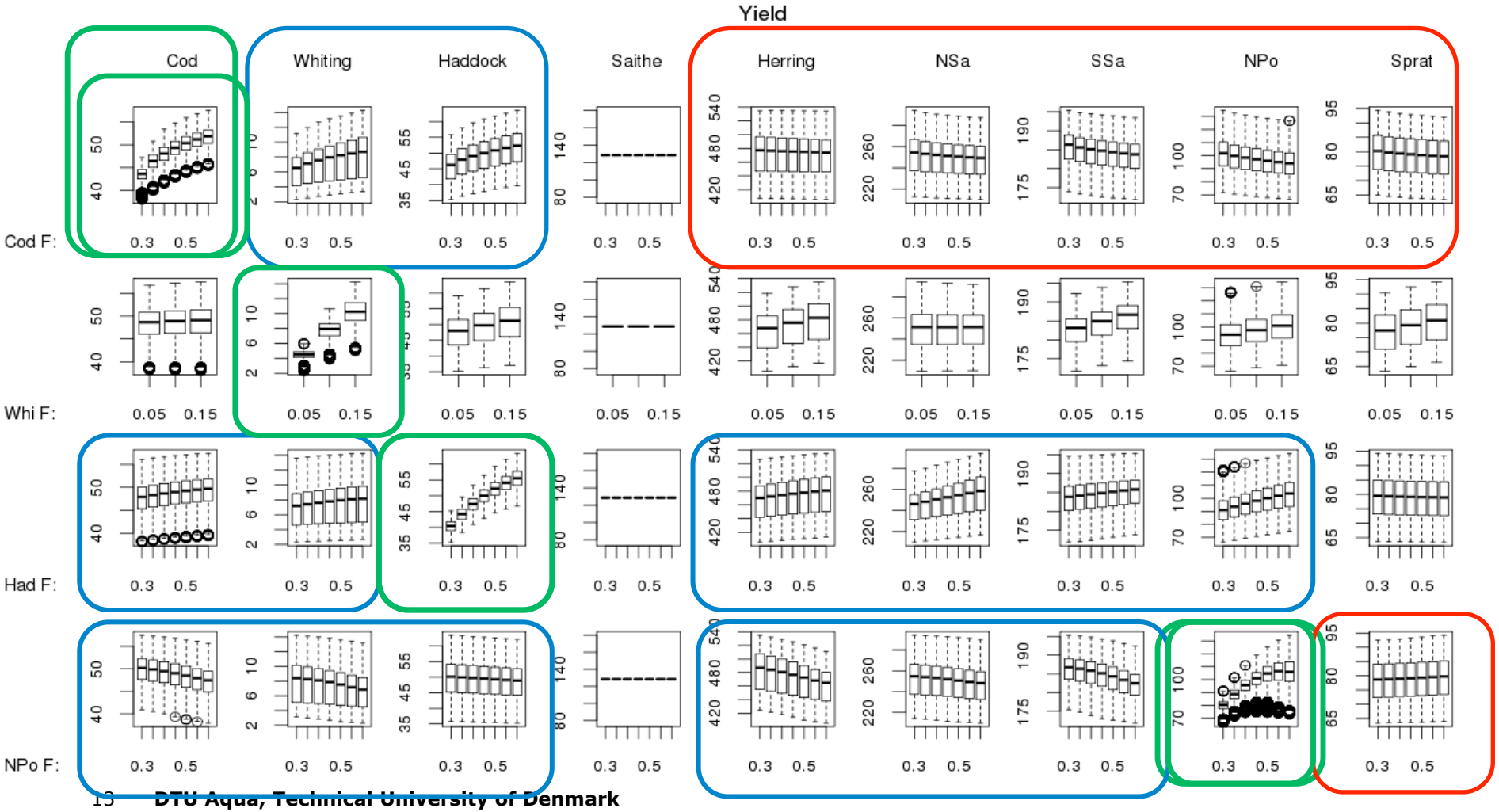


Yield

Mainly direct predation effects of species F

Effects of species F

Mainly indirect predation effects



What are the targets ?

- MSY: Highest yield or value, **by species**
- MSFD: healthy stocks, large stocks

- MY Scenario objectives
  - SSB > Bpa (MSFD)
  - pretty good yield, e.g. 95% of MSY

Yield relative to observed Maximum Yield

	Fishing mortality												
	0.05	0.1	0.15	0.25	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7
Cod	.	.	.	.	0.84	0.90	**0.93**	**0.95**	**0.97**	**0.99**	**1.00**	.	.
Whiting	0.44	0.77	**1**	.	.	.	.	.	.	.	.	.	.
Haddock	.	.	.	.	0.73	0.80	0.85	0.90	0.94	0.97	1.00	.	.
Saithe	.	.	.	.	.	.	1.00	.	.	.	.	.	.
Herring	.	.	.	0.86	0.93	0.98	1.00	.	.	.	.	.	.
N. sandeel	.	.	.	.	.	.	0.82	0.89	0.94	0.98	1.00	.	.
S. sandeel	.	.	.	.	0.94	0.99	1.00	0.98	**0.97**	.	.	.	.
Nor. pout	.	.	.	.	0.75	0.83	0.90	0.95	0.98	1.00	**1.00**	.	.
Sprat	.	.	.	.	.	.	0.77	0.82	0.86	0.90	0.94	0.97	1

PRUNING

1. Exclude high F for **prey species** for SSB<Bpa
2. Exclude high F for **predator species**, for SSB<<Bpa
3. Exclude low F for **all species** for yield << MSY
4. Start from 1

Red values include F leading to median(SSB) below Bpa

Yield relative to observed Maximum Yield

	Fishing mortality											
	0.1	0.15	0.25	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7
Cod	.	.	.	0.86	0.92	**0.95**	**0.98**	**1.00**	.	.	.	.
Whiting	0.77	**1**	.	.	.	.	.	.	.	.	.	.
Haddock	.	.	.	0.72	0.79	0.85	0.90	0.94	0.97	1.00	.	.
Saithe	.	.	.	.	.	1.00	.	.	.	.	.	.
Herring	.	.	0.86	0.93	0.97	1.00	.	.	.	.	.	.
N. sandeel	.	.	.	.	.	0.82	0.88	0.94	0.98	**1.00**	.	.
S. sandeel	.	.	.	0.94	0.99	1.00	0.98	.	.	.	.	.
Nor. pout	.	.	.	0.74	0.82	0.89	0.94	0.98	1.00	.	.	.
Sprat	.	.	.	.	.	0.77	0.83	0.86	0.90	0.94	0.97	1

PRUNING

1. Exclude high F for **prey species** for SSB<Bpa
2. Exclude high F for **predator species**, for SSB<<Bpa
3. Exclude low F for all species for yield << MSY (Now 85%)
4. Start from 1

Yield relative to observed Maximum Yield

	Fishing mortality										
	0.15	0.25	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7
Cod	.	.	0.90	**0.97**	**1.00**	.	.	.	.	.	.
Whiting	**1**	.	.	.	.	.	.	.	.	.	.
Haddock	.	.	.	.	0.85	0.90	0.94	0.97	1.00	.	.
Saithe	.	.	.	.	1.00	.	.	.	.	.	.
Herring	.	0.86	0.93	0.97	1.00	.	.	.	.	.	.
N. sandeel	.	.	.	.	.	0.90	0.96	1.00	.	.	.
S. sandeel	.	.	0.94	0.99	1.00	0.98	.	.	.	.	.
Nor. pout	.	.	.	.	0.87	0.93	0.97	1.00	.	.	.
Sprat	.	.	.	.	.	.	0.86	0.90	0.94	0.97	1

PRUNING

1. Exclude high F for **prey species** for SSB<Bpa
2. Exclude high F for **predator species**, for SSB<<Bpa
3. Exclude low F for all species for yield << MSY (now 90%)
4. Start from 1

Yield relative to observed Maximum Yield

Fishing mortality

	0.15	0.25	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7
Cod	.	.	0.93	**1.00**	.	.	.	.	.	.	.
Whiting	**1**	.	.	.	.	.	.	.	.	.	.
Haddock	.	.	.	.	.	0.90	0.94	0.97	1.00	.	.
Saithe	.	.	.	.	1	.	.	.	.	.	.
Herring	.	0.86	0.93	0.97	1	.	.	.	.	.	.
N. sandeel	.	.	.	.	.	0.90	0.96	1.00	.	.	.
S. sandeel	.	.	0.94	0.99	1	0.98	.	.	.	.	.
Nor. pout	.	.	.	.	.	0.93	0.97	1.00	.	.	.
Sprat	.	.	.	.	.	.	.	0.90	0.94	0.97	1

PRUNING

1. Exclude high F for **prey species** for SSB<Bpa
2. Exclude high F for **predator species**, for SSB<<Bpa
3. Exclude low F for all species for yield << MSY (now ~93%)
4. Start from 1

Yield relative to observed Maximum Yield

	Fishing mortality									
	0.15	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7
Cod	.	0.94	1.00	.	.	.	.	.	.	.
Whiting	1	.	.	.	.	.	.	.	.	.
Haddock	.	.	.	.	.	0.94	0.97	1.00	.	.
Saithe	.	.	.	1	.	.	.	.	.	.
Herring	.	.	0.97	1	.	.	.	.	.	.
N. sandeel	.	.	.	.	.	0.96	1.00	.	.	.
S. sandeel	.	.	0.99	1	0.98	.	.	.	.	.
Nor. pout	.	.	.	.	.	0.97	1.00	.	.	.
Sprat	.	.	.	.	.	.	.	0.94	0.97	1

PRUNING

1. Exclude high F for **prey species** for SSB<Bpa
2. Exclude high F for **predator species**, for SSB<<Bpa
3. Exclude low F for all species for yield << MSY (now ~95%)
4. Start from 1

Yield relative to observed Maximum Yield

	Fishing mortality								
	0.15	0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7
Cod	.	1.00	.	.	.	.	.	.	.
Whiting	1	.	.	.	.	.	.	.	.
Haddock	.	.	.	.	.	0.97	1	.	.
Saithe	.	.	1	.	.	.	.	.	.
Herring	.	0.97	1	.	.	.	.	.	.
N. sandeel	.	.	.	.	0.96	1.00	.	.	.
S. sandeel	.	0.99	1	0.98	.	.	.	.	.
Nor. pout	.	.	.	.	0.98	1.00	.	.	.
Sprat	.	.	.	.	.	.	.	0.97	1

Median(SSB):

Cod: 161 kt (Bpa=165)

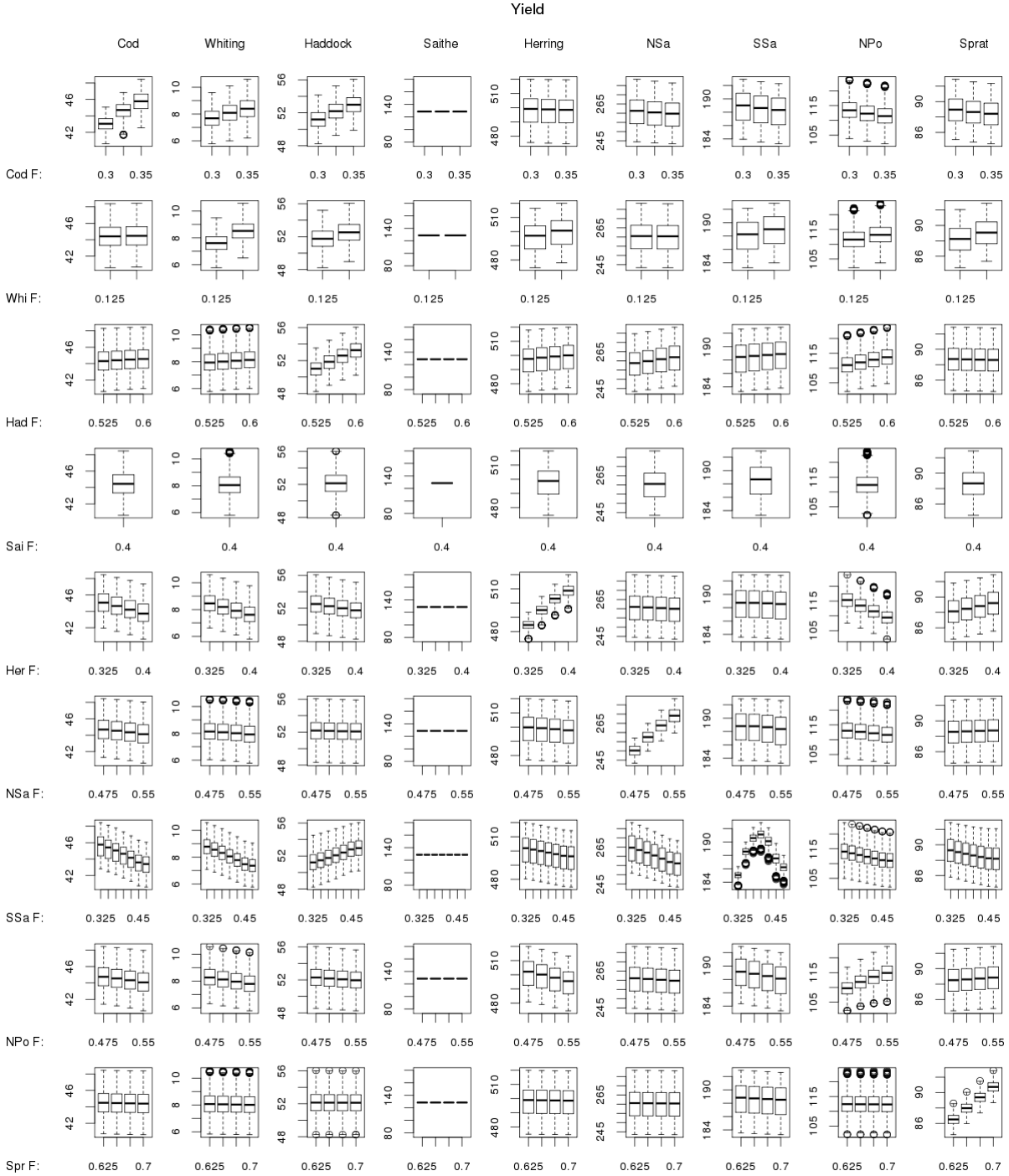
Whiting: 148 kt (Bpa=170kt)

Yield relative to observed Maximum Yield

	0.125	0.15	0.3	0.325	0.35	0.375	0.4	0.425	0.45	0.475	0.5	0.525	0.55	0.575	0.6	0.625	0.65	0.675	0.7
Cod	.	.	0.94	0.98	1.00	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Whiting	0.89	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Haddock	.	.	.	.	.	.	.	.	.	.	.	0.96	0.97	0.99	1	.	.	.	.
Saithe	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.
Herring	.	.	.	0.95	0.97	0.99	1	.	.	.	.	.	.	.	.	.	.	.	.
N. sandeel	.	.	.	.	.	.	.	.	.	0.93	0.96	0.98	1.00	.	.	.	.	.	.
S. sandeel	.	.	.	0.97	0.99	1.00	1	0.99	0.98	0.97	.	.	.	.	.	.	.	.	.
Nor. pout	.	.	.	.	.	.	.	.	.	0.95	0.97	0.99	1.00	.	.	.	.	.	.
Sprat	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.95	0.97	0.99	1

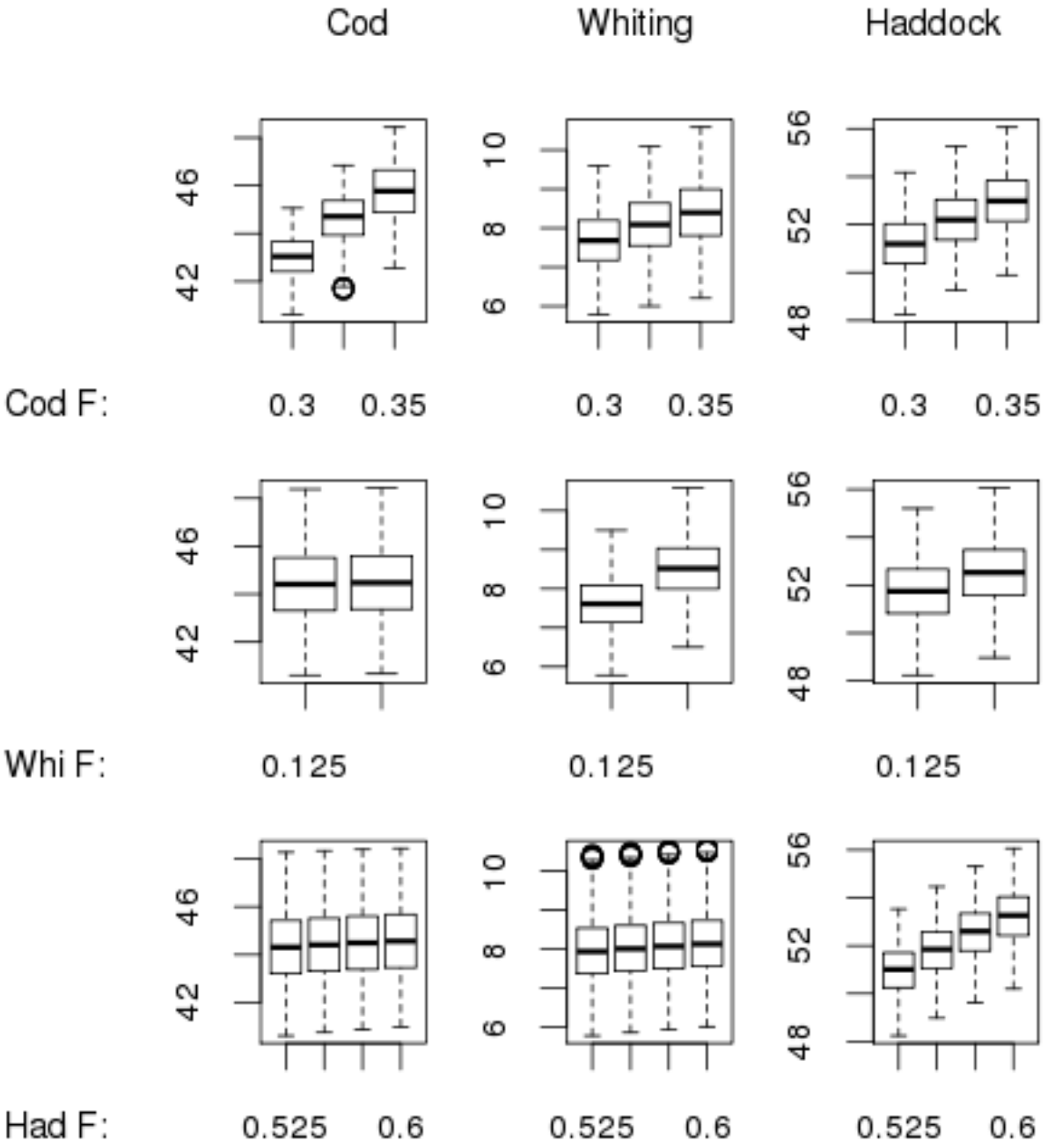
	95% FMSY range
Cod	0.30-0.35
Whiting	0.13-0.15
Haddock	0.53-0.58
Saithe	0.40
Herring	0.33-0.40
N. sandeel	0.50-0.55
S. sandeel	0.35-0.50
Nor. pout	0.50-0.58
Sprat	0.63-0.70

Yield


Yield
Cod
Whiting
Haddock
Saithe
Herring
NSa
SSa
NPo
Sprat
Cod F:
Whi F:
Had F:
Sai F:
Her F:
NSa F:
SSa F:
NPo F:
Spr F:

Pretty good

Yield!



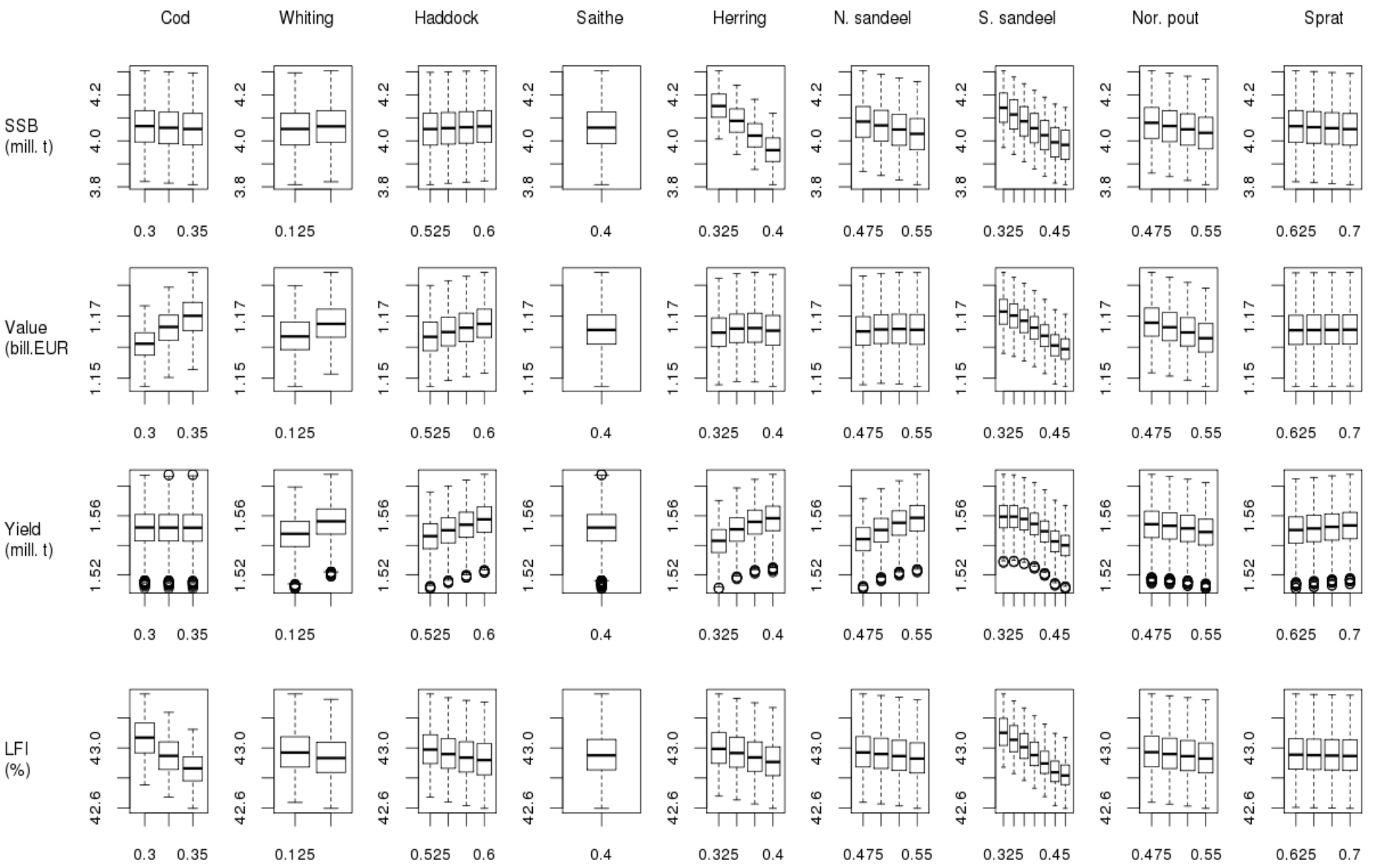
FMSY and FMSY ranges

	Multispecies 95% FMSY range*	ICES 95% FMSY range	Maximize value, penalize SSB<Bpa	Maximize yield penalize SSB < Bpa
Cod	0.30-0.35	0.22-0.42	0.34	0.35
Whiting	0.13-0.15	0.074**	0.15	0.14
Haddock	0.53-0.58	0.25-0.52**	0.58	0.60
Saithe	0.40	0.21-0.57**	0.38	0.40
Herring	0.33-0.40	0.24-0.51**	0.33	0.37
N. sandeel	0.50-0.55		0.40	0.40
S. sandeel	0.35-0.50		0.17	0.29
Nor. pout	0.50-0.58		0.15	0.36
Sprat	0.63-0.70		0.10	0.60

* F<=Fpa and SSB>Bpa

** ICES WKMSYREF3

System indicators (SSB, Value, Yield and LFI)



Summary

- There is no single combination of F that provides MSY in a multispecies context

- Within a 95% MSY range, species F and predation effects on yield are of the same magnitude

- FMSY obtained from maximization doesn't really work!
  - Requires objective function, constrains and penalties (which we will never get from stakeholders)
  - ”Black box” approach.

- ”Pretty good Yield”, illustration of trade offs
  - MSY by species, rather than yield for the for the whole system
  - Complex, however we can explain what goes on
  - May be extended to inform ”Ecosystem approach to management”
  - Conclusions drawn may be useful for ”adaptive management”

Thank you !