Results fro the EU SC05 project: "Multispecies Fisheries Assessment for NAFO"

European Maritime and Fisheries Fund
Framework Programme UE EMFF/2016/008

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SCO5 Project tasks
Overview

- **Task 1:** Setting the context
  - A general overview of the multispecies approach worldwide
  - Description of the biological, ecological, fishery and scientific features of the Flemish Cap.
- **Task 2:** Updating **GadCap**
  - An updated version of the multispecies model GadCap: a gadget cod, redfish an shrimp **multispecies model in the Flemish Cap**.
- **Task 3:** First approach to implement multispecies assessment
  - Explore the provision of scientific advice for a multispecies approach in the Flemish Cap
    - Use of multispecies natural mortality estimates in stock assessment
    - **Multispecies MSE framework and potential new multispecies HCRs.**
- **Task 4:** Economyc trade-offs
  - First analysis of the socio/economic implications
  - Available techniques and models needed to assess the trade-offs
- **Task 5:** Dissemination to scientists and stakeholders
  - Discussion and interaction between scientists and other stakeholders: workshop.
  - Presentation and integration of results in the NAFO-WGESA and NAFO Scientific Council meetings
- **Task 6:** Further research
  - Identify future necessary steps and research activities

SCO5 Project tasks
Overview

- **<u>Task 2:</u> Updating GadCap**
  - An **updated version** of the multispecies **model GadCap**: a gadget cod, redfish an shrimp multispecies model in the Flemish Cap.
- **<u>Task 3:</u> First approach to implement multispecies assessment**
  - Explore the provision of scientific advice for a multispecies approach in the Flemish Cap
    - Use of **multispecies natural mortality** estimates in stock assessment
    - **Multispecies MSE framework and potential new multispecies HCRs.**
- **<u>Task 4:</u> Economyc trade-offs**
  - First analysis of the **socio/economic implications**
  - Available techniques and models needed to assess the trade-offs

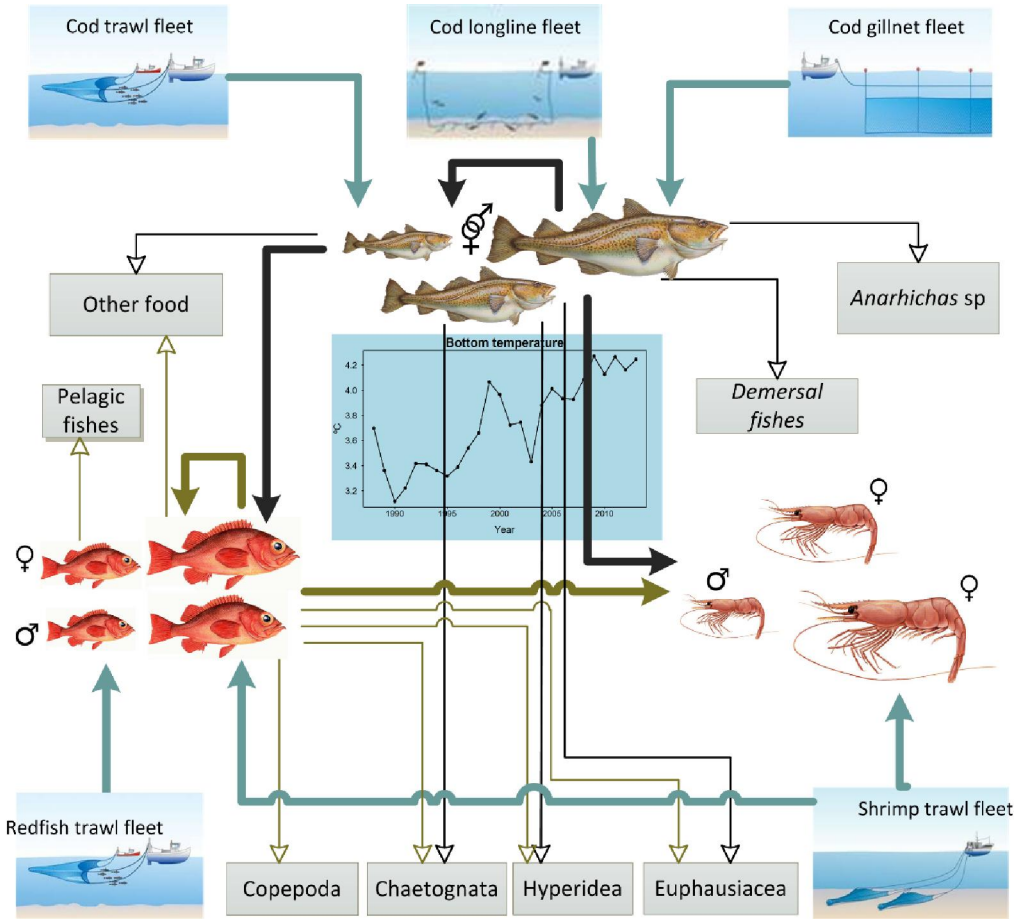
Framework for MP evaluation (Punt and Donovan, 2007)

1. Specification of **management objectives** with associated **statistics to measure performance** of a MP against these objectives
2. Specification of **candidate MPs**
3. Specification of **population dynamic operating models** with which to represent status and behaviour of the resource under alternative MPs
4. **Simulation of candidate MP performance** into the future, including at each time step: a) generation of observational data; b) application of the MP; c) operating model projection assuming MP outputs (**running an MSE**)
5. Collation of performance statistics and selection of the MP most likely to reach management objectives.

Steps to define HCRs and analyse trade-offs:

1. Multispecies model (SCO5-Task 2)

Task 2: GadCap



-**Gadget** (Globally applicable Area Dissagregated General Ecosystem Toolbox)

•Age-length based model

Biological processes:
•Growth
• Maturation
• Sex change
• Length-weight relationship
• Residual mortality

Ecology related components
•Consumption
•Diet composition
• Prey preference
•Prey-predator size relationship
• Prey-predator suitability function

linearfleet: catches are modelled
•Trawl and longline: sigmoid
•Gillnet: dome shaped
• Redfish bycatch in shrimp fishery: dome shaped

Pérez-Rodríguez, A. and D. González Troncoso (2018). "Update of the Flemish Cap multispecies model GadCap as part of the EU SC05 project: "Multispecies Fisheries Assessment for NAFO"." NAFO SCR Doc. 18/024.

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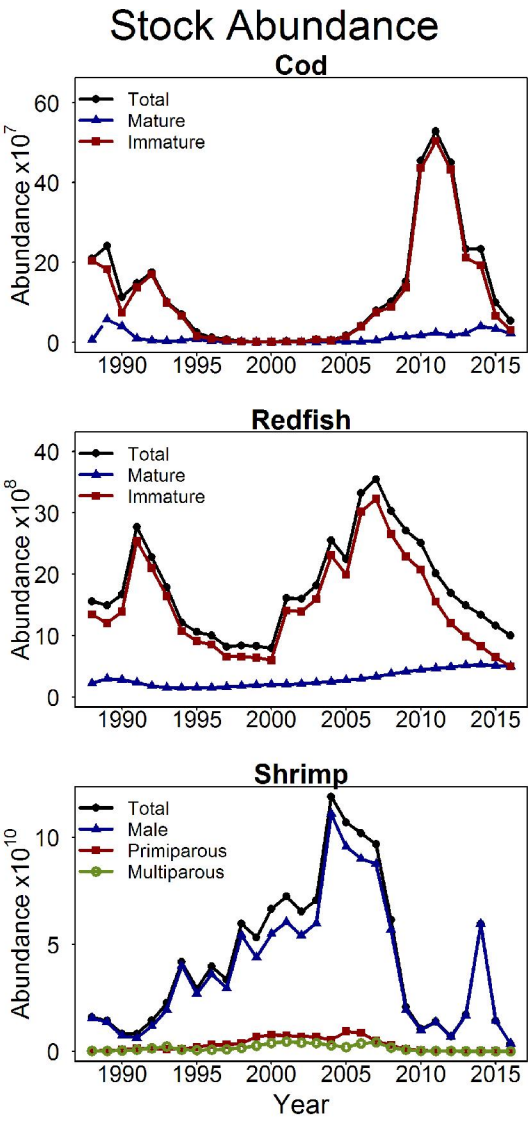
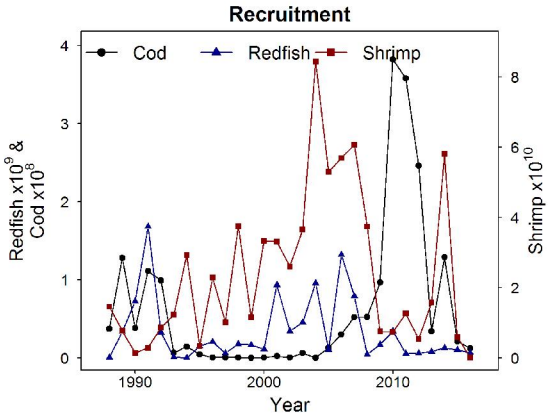
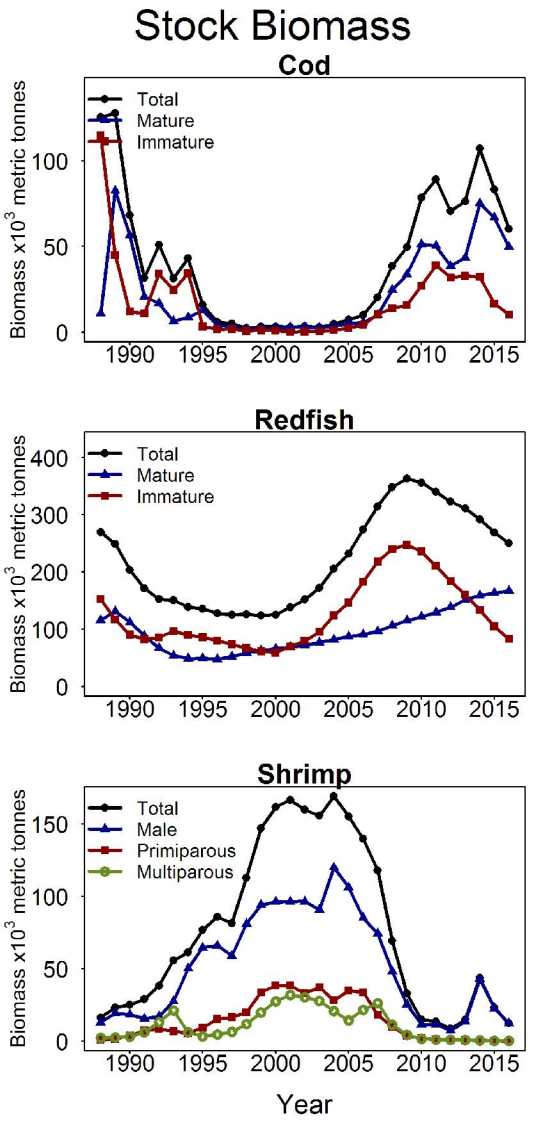
Abundance, recruitment and Biomass

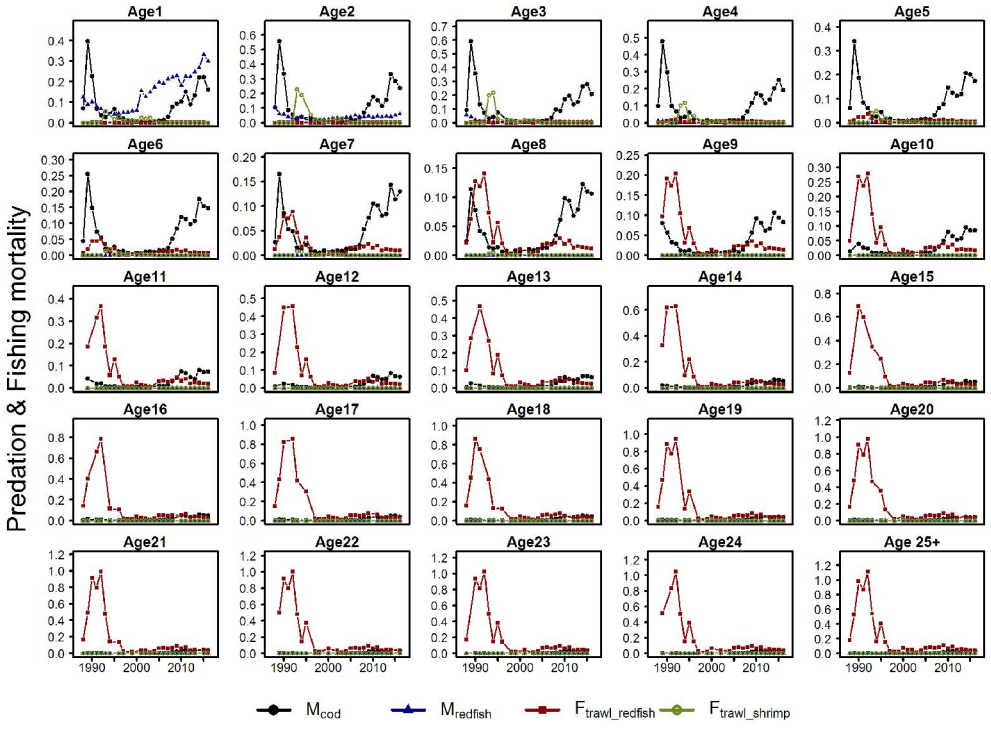




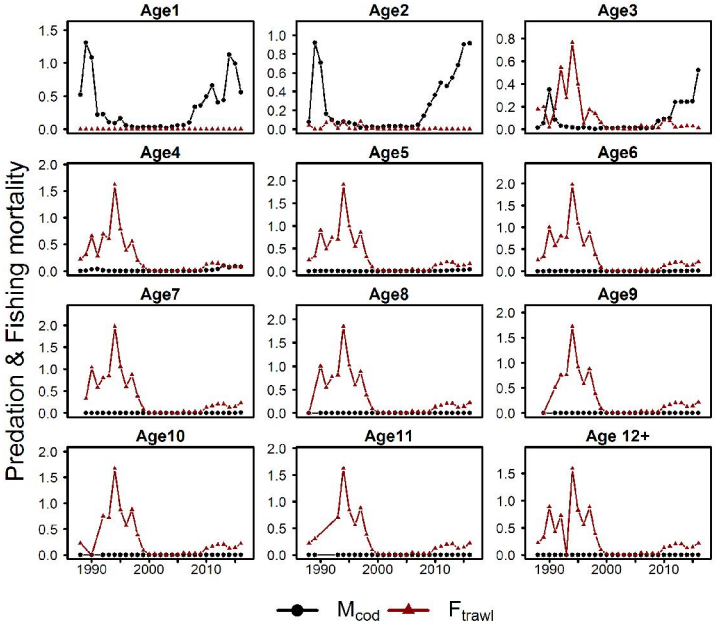


Fishing and Predation mortality at age

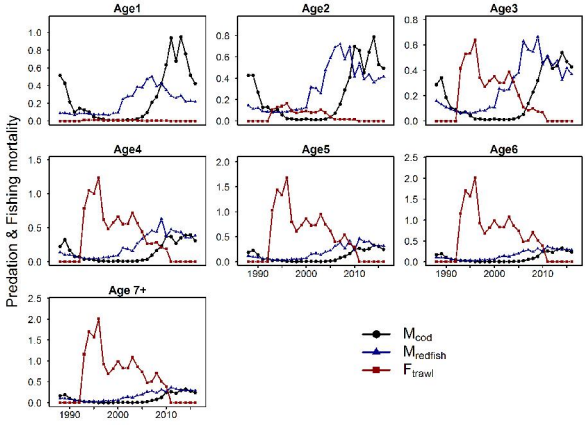
Redfish



Cod



Shrimp



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Connection SC03 and SC05: Estimates of natural predation and residual mortality for the Flemish Cap cod

- DG-MARE SC03:

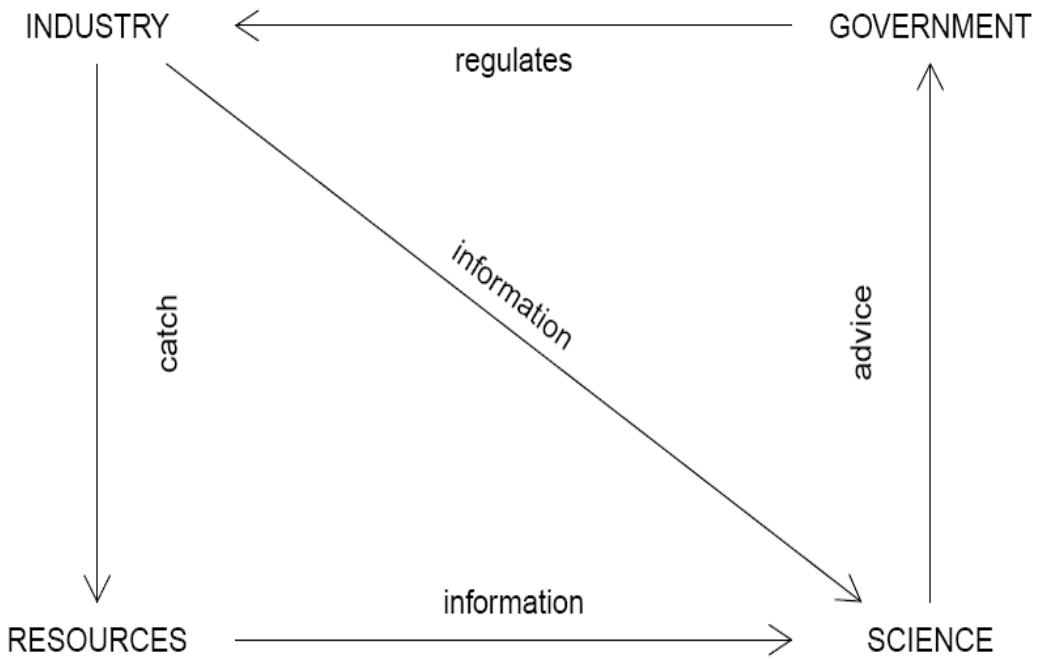
"Support to a robust model assessment, benchmark and development of a management strategy evaluation for cod in NAFO division 3M"

  - Task 2: 3M cod benchmark
  - Testing different option for Natural mortality
    - Constant M at age and over time
    - Vector of variable M at age, but constant over time
    - **Matrix of variable M at age and over time** (connection with SC05, estimates of M2 from GadCap)

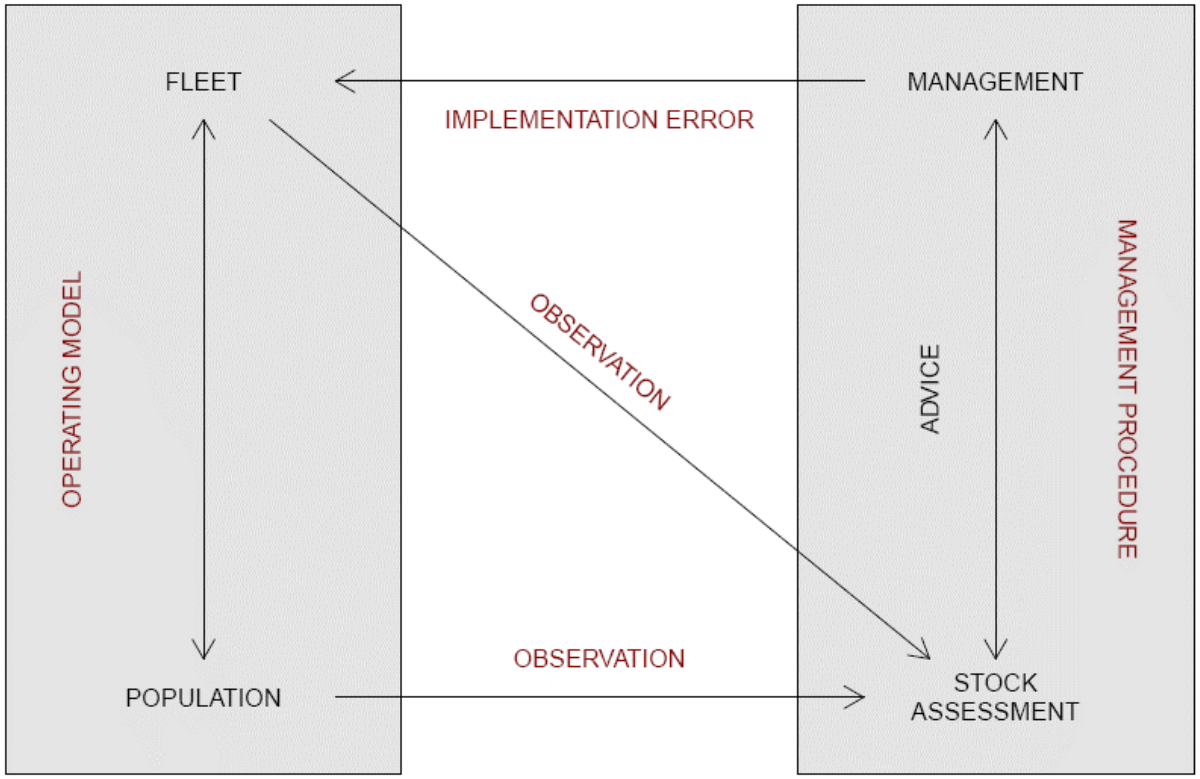
Steps to define HCRs and analyse trade-offs:

1. Multispecies model (SCO5-Task 2)
2. MSE framework (SCO5-Task 3)

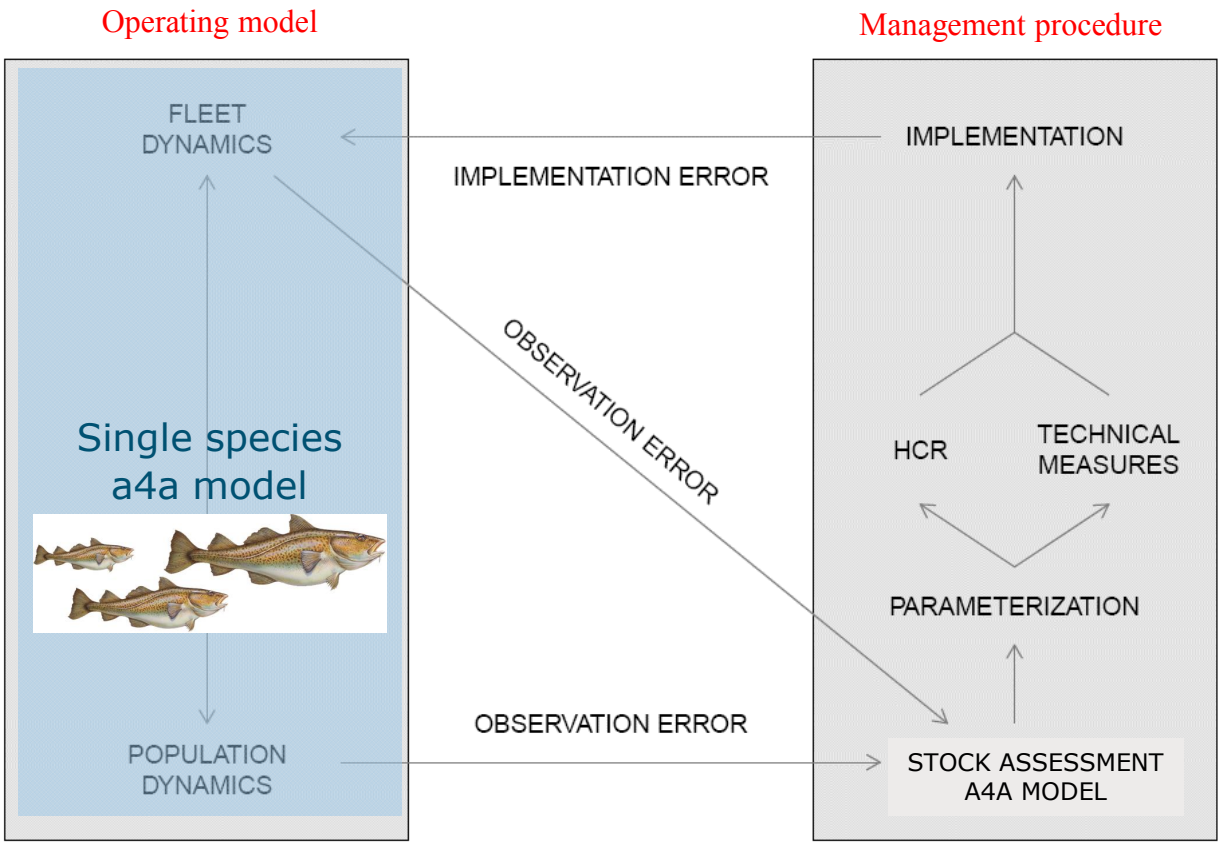
Management cycle



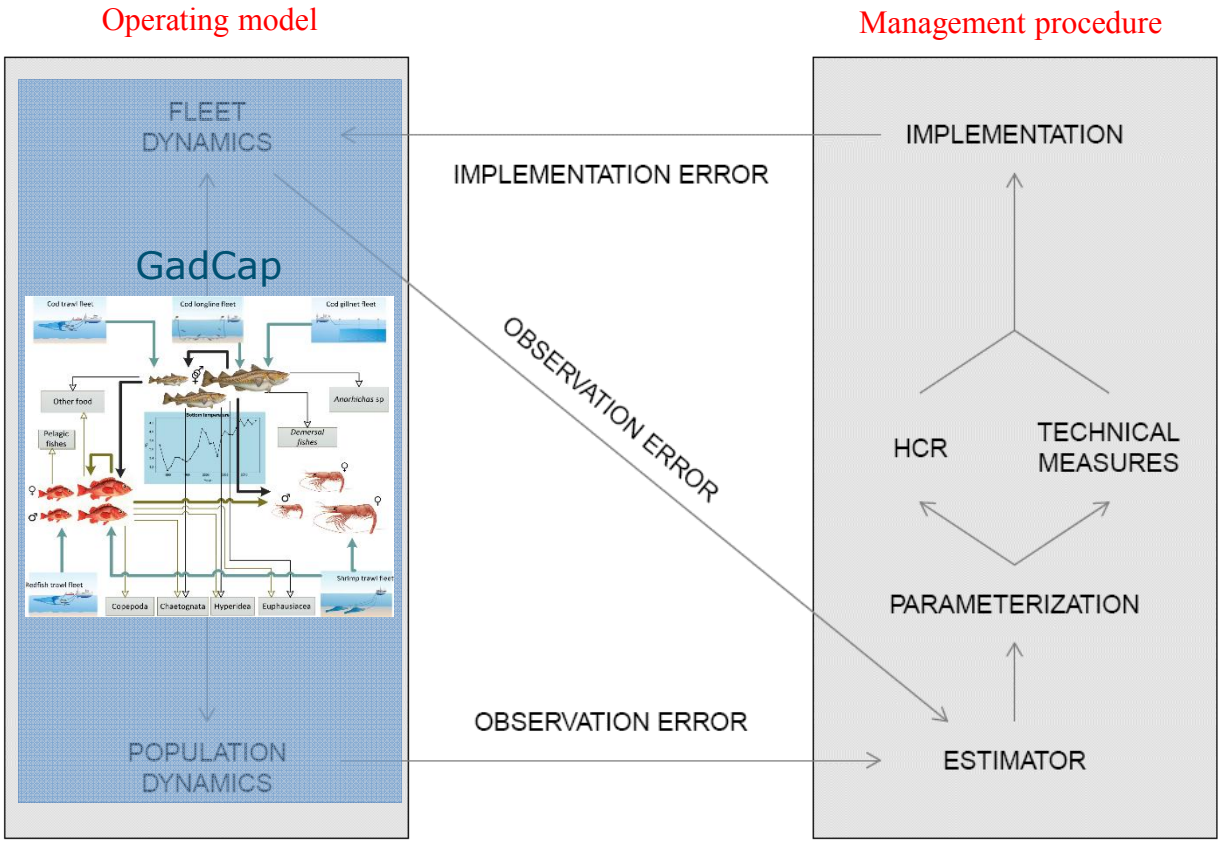
Including the management cycle in an MSE framework



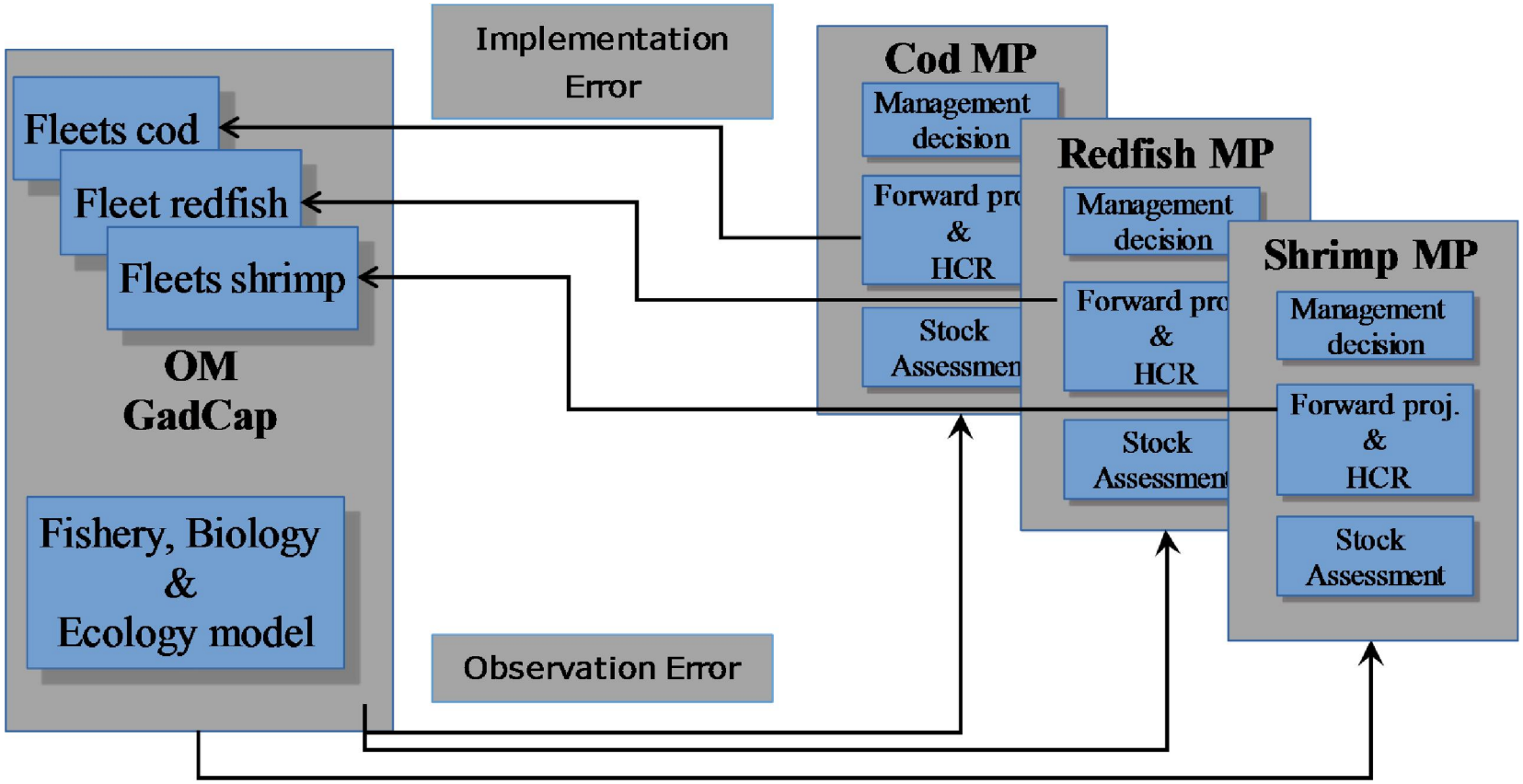
a4a-MSE framework: EU JRC-Ispra



Adapting a4a (FLR)-MSE framework: GadCap as operating model



Adapting a4a (FLR)-MSE framework: GadCap as operating model

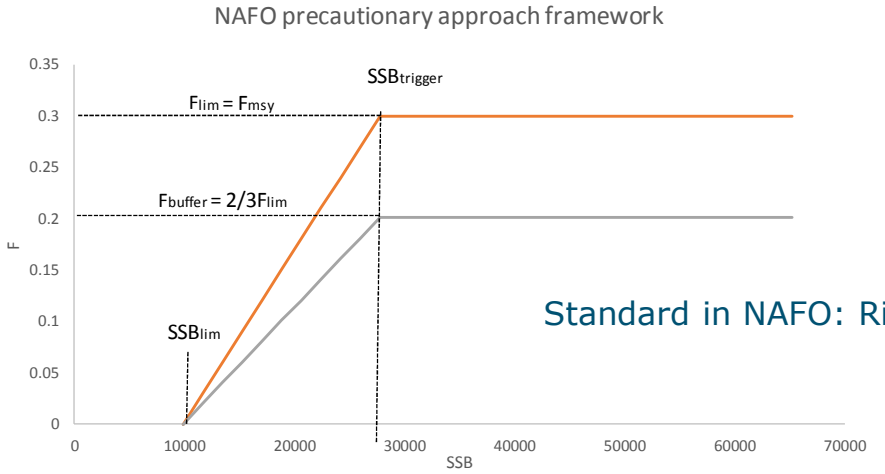


Stock assessment
- Shortcut (assessment error)
- SCAA a4a

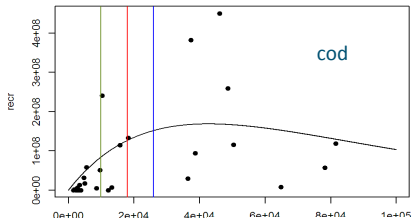
Steps to define HCRs and analyse trade-offs:

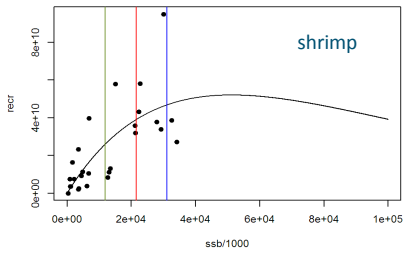
1. Multispecies model (SCO5-Task 2)
2. MSE framework (SCO5-Task 3)
3. Define HCRs (SCO5-Task 3):
    - Blim and Btrigger

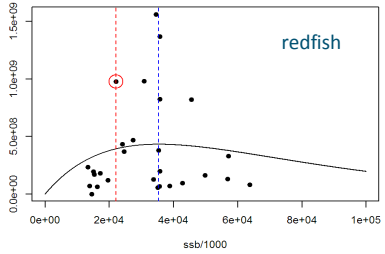
Estimating reference points: Blim and Btrigger



Standard in NAFO: Risk SSB below Blim lower than 10%







species	Blim	Btr
cod	17906	25943
redfish	22027	35361
shrimp	11864	31114

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Steps to define HCRs and analyse trade-offs:

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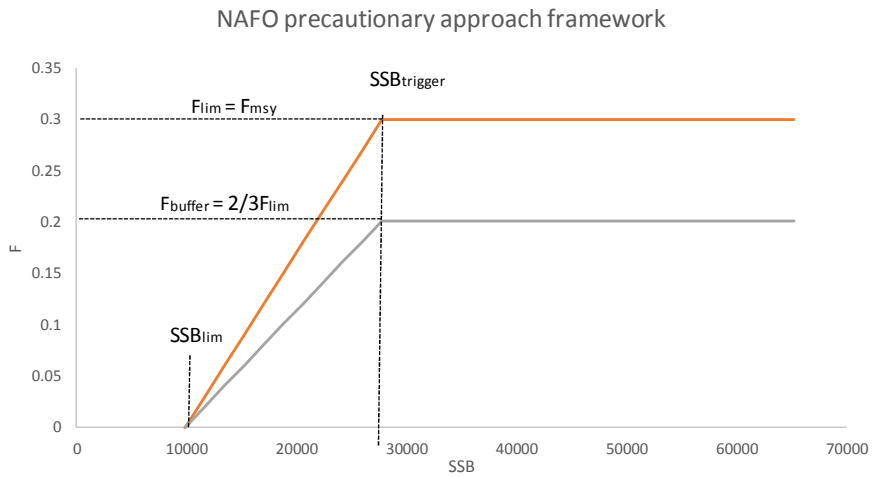
3. Define HCRs (SCO5-Task 3):
    - Blim and Btrigger
    - Estimate candidate single and multispecies F reference points deterministically

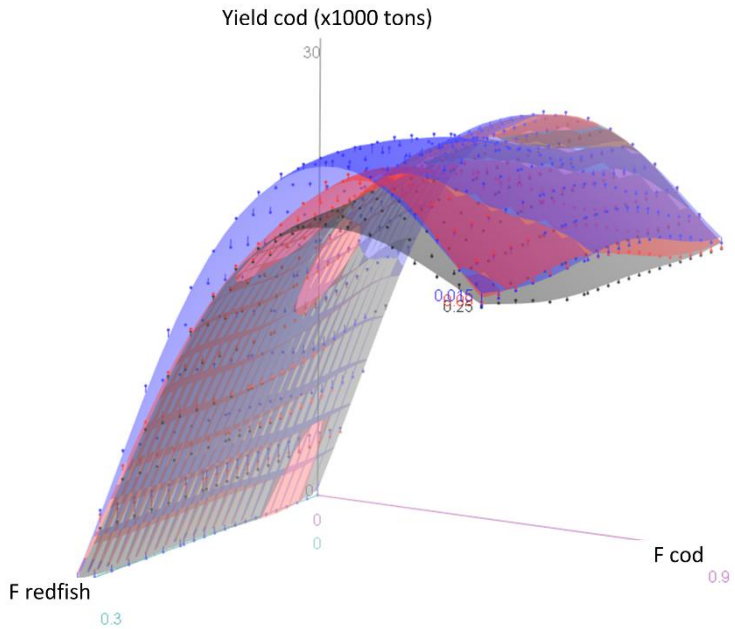


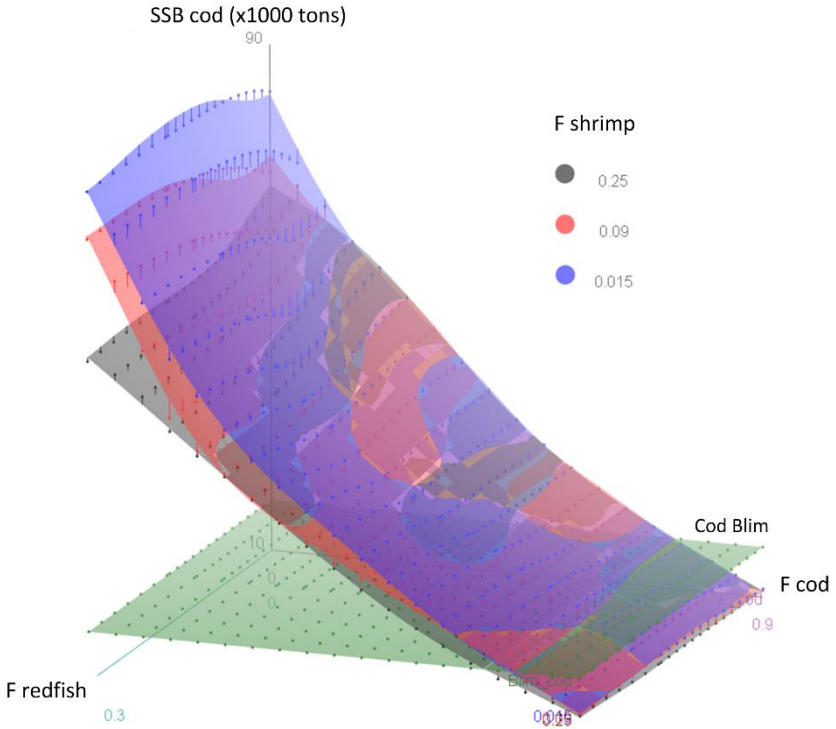
Long term projections

- 2017-2050
- Ricker SSB-Recruitment
- Only trawl fleets (cod, redfish and shrimp)
- Run 8000 F combinations (20 F values per species)
- For each combination calculate the mean SSB and yield in the period 2035-2050.

F_{cod}	F_{red}	F_{shrimp}
0	0	0
0.05	0.015	0.015
0.1	0.03	0.03
0.15	0.045	0.045
0.2	0.06	0.06
0.25	0.075	0.075
0.3	0.09	0.09
0.35	0.105	0.105
0.4	0.12	0.12
0.45	0.135	0.135
0.5	0.15	0.15
0.55	0.165	0.165
0.6	0.18	0.18
0.65	0.195	0.195
0.7	0.2	0.2
0.75	0.225	0.225
0.8	0.25	0.25
0.85	0.275	0.275
0.9	0.3	0.3
0.95	0.325	0.325

Yield and SSB curves
Cod





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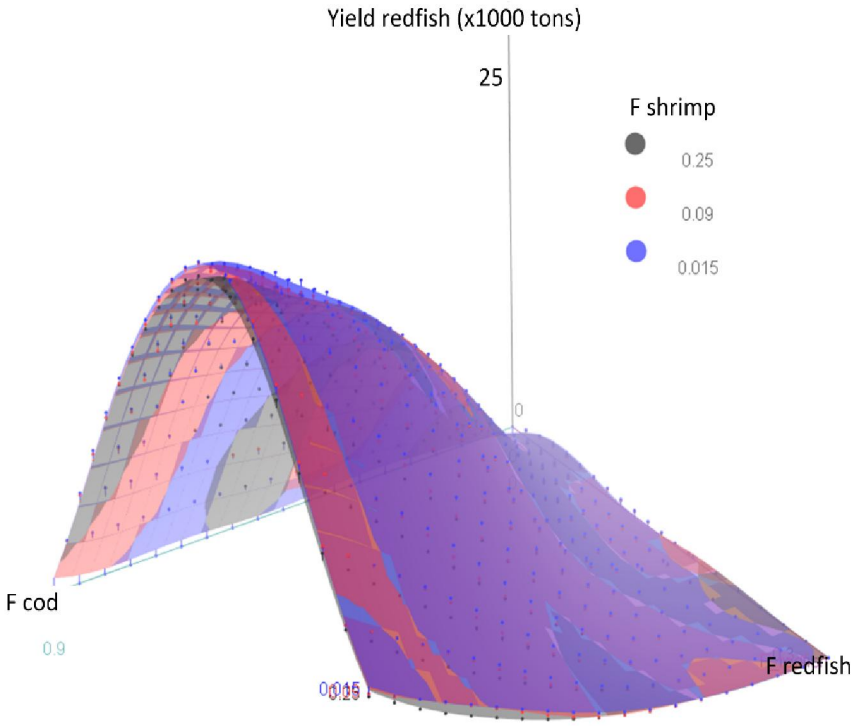
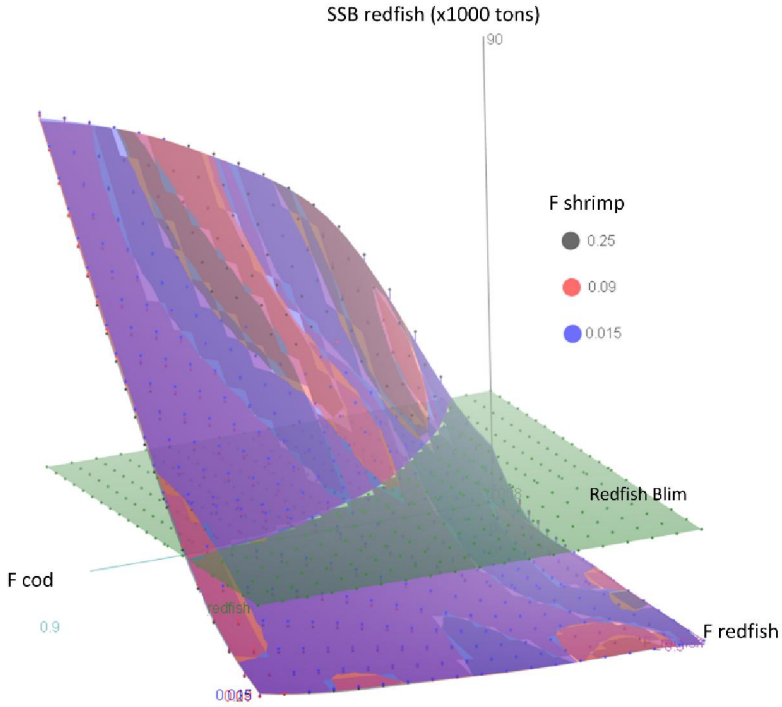
Yield and SSB curves Redfish





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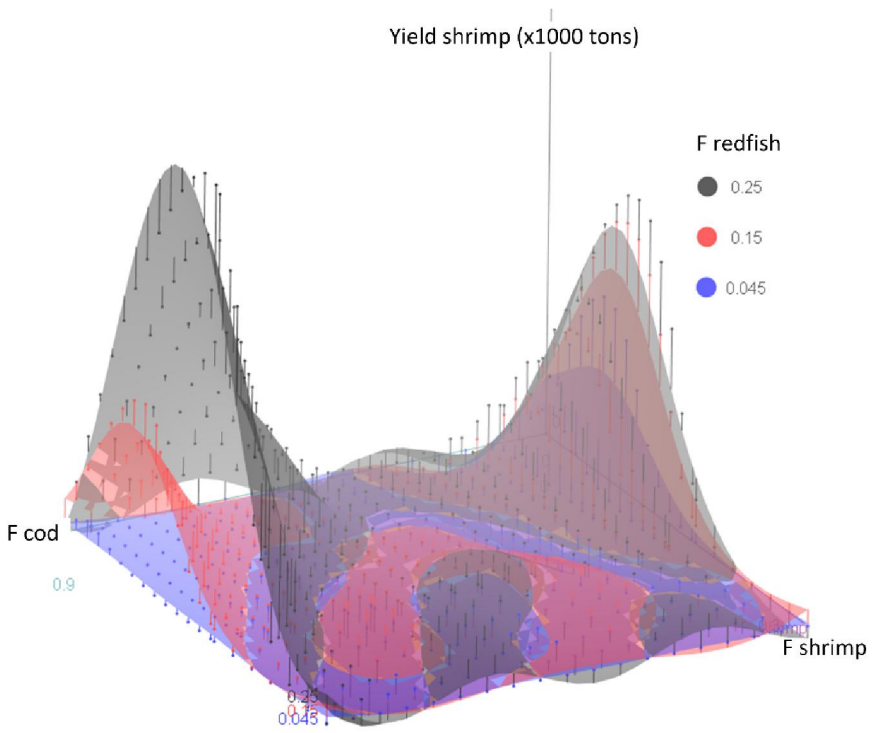
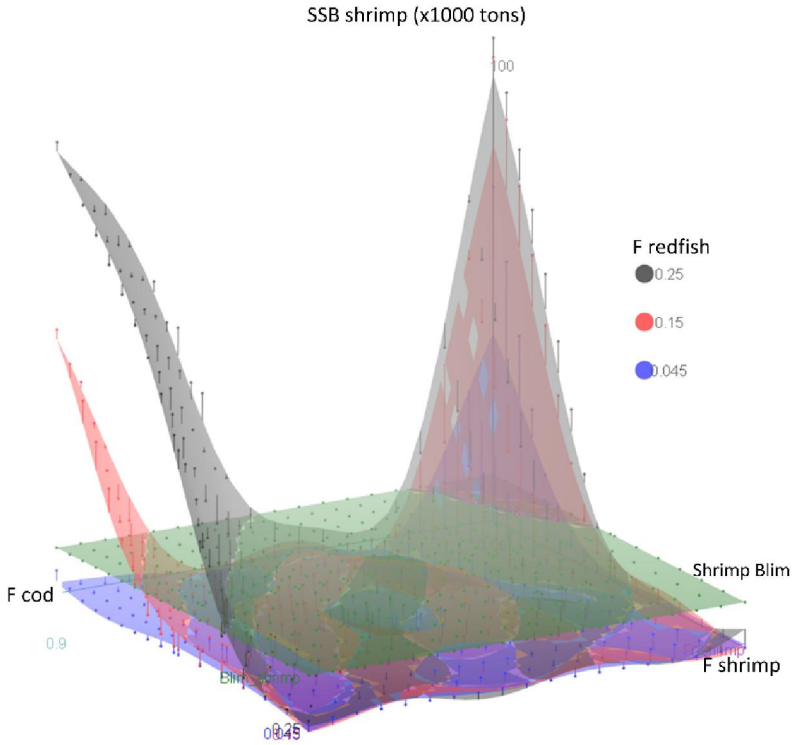
Yield and SSB curves
Shrimp





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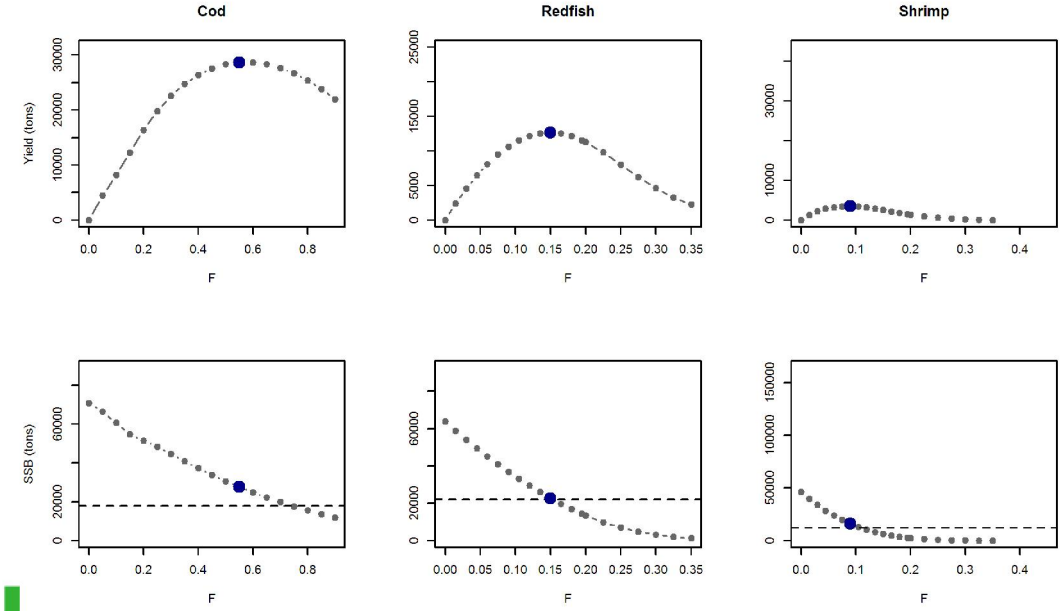
Candidate single species F reference values

- Calculate for each species the mean value of SSB and yield for each F tested (mean of 400 combinations) in the period 2035-2050.
- Select the F (Fmsy, Flim in NAFO) that produces the highest yield while SSB is above Blim in a deterministic way.
- Estimate Ftarget as 2/3*Flim: standard in NAFO when using a deterministic model.



species	Fmsy	yield	ssb	Ftarget
cod	0.55	28652	27605	0.367
Redfish	0.15	12669	22689	0.1
shrimp	0.09	3463	16050	0.06

Candidate multispecies F reference values

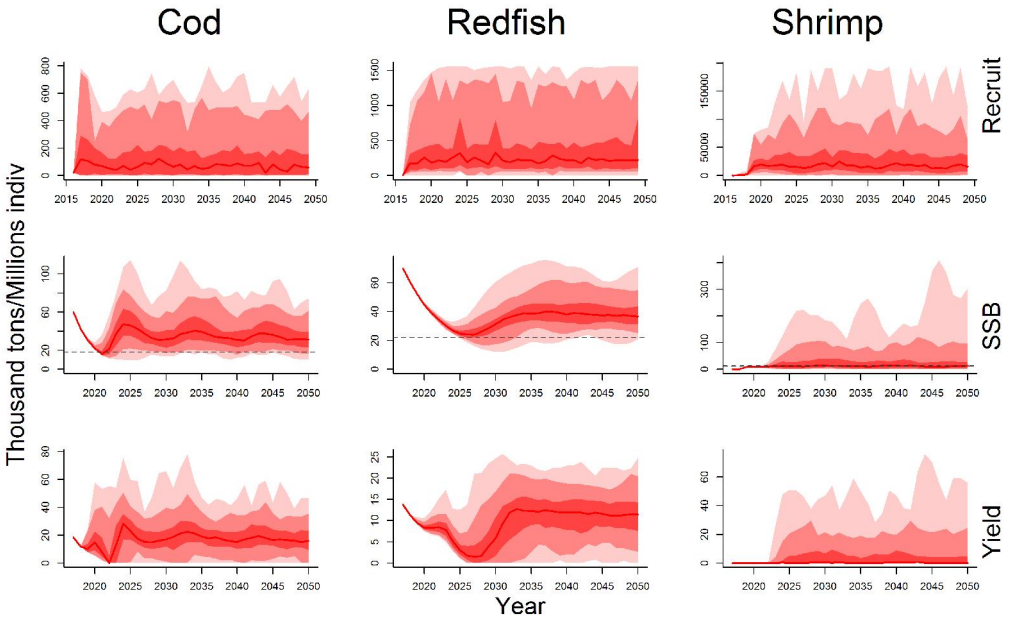
- Find combinations of F that keep the three species above Blim in a Deterministic way
- Only 96 out of 8000 combinations
- Selection of 12 combinations:

Criteria_code	Criteria	F_cod	F_redfish	F_shrimp
1	3 stocks above Blim	0.55	0.18	0
1	3 stocks above Blim	0.6	0.165	0
1	3 stocks above Blim	0.65	0.165	0
1	3 stocks above Blim	0.65	0.165	0.015
1	3 stocks above Blim	0.65	0.165	0.03
1	3 stocks above Blim	0.65	0.195	0
1	3 stocks above Blim	0.65	0.195	0.015
1	3 stocks above Blim	0.65	0.195	0.03
1	3 stocks above Blim	0.65	0.195	0.045
1	3 stocks above Blim	0.65	0.195	0.06
1	3 stocks above Blim	0.75	0.2	0
1	3 stocks above Blim	0.75	0.2	0.06
1	3 stocks above Blim	0.75	0.2	0.075

Steps to define HCRs and analyse trade-offs:

1. Multispecies model (SCO5-Task 2)
2. MSE framework (SCO5-Task 3)
3. Define HCRs (SCO5-Task 3):
    - Blim and Btrigger
    - Estimate candidate single and multispecies F reference points deterministically
    - Risk assessment of HCRs considering recruitment uncertainty and assessment error (SCO5-Task 3)

Risk analysis with recruitment uncertainty
Single species F candidates

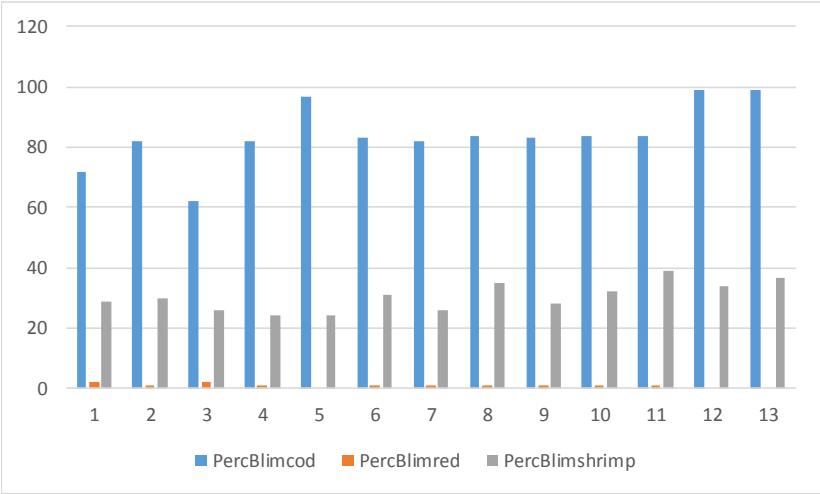


species	Ftarget	Perc_below_Blim
cod	0.353	51
redfish	0.1	10
shrimp	0.067	91

- Ftarget (2/3*Fmsy) seems **not precautionary** when estimated in isolation of the other species, excepting for redfish, that benefits from low cod biomass.
- However, in the **medium term it is not precautionary for redfish**

Risk analysis with recruitment uncertainty Multispecies F candidates

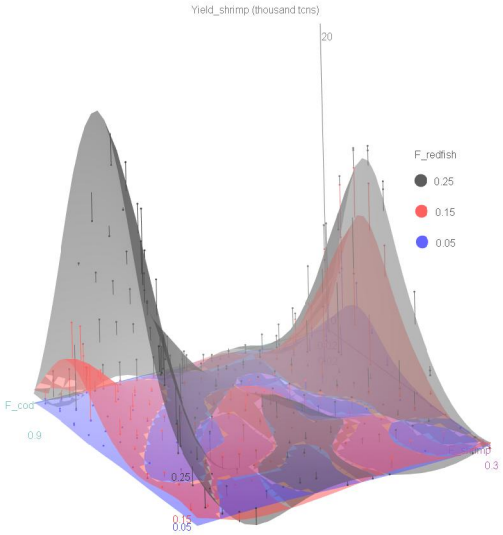
combination	Ftargetcod	Ftargetred	Ftargetshrimp
1	0.6	0.165	0
2	0.65	0.165	0
3	0.55	0.18	0
4	0.65	0.195	0
5	0.75	0.2	0
6	0.65	0.165	0.015
7	0.65	0.195	0.015
8	0.65	0.165	0.03
9	0.65	0.195	0.03
10	0.65	0.195	0.045
11	0.65	0.195	0.06
12	0.75	0.2	0.06
13	0.75	0.2	0.075

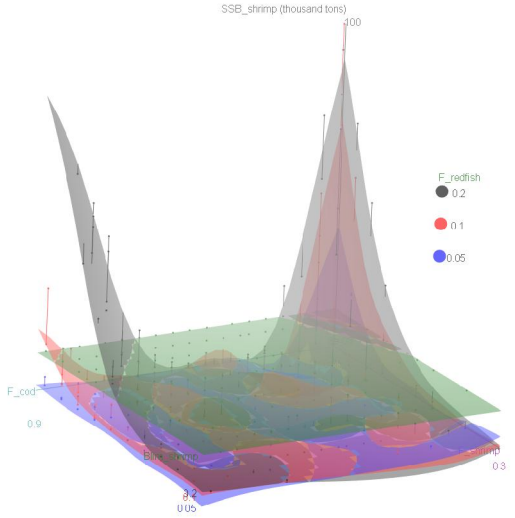


- Very **similar pattern for all the 13 F combinations**:
- The F values required to keep all the three species above Blim in a deterministic way entails a very **high risk of collapse** when recruitment uncertainty is considered
- High risk SSBcod<Blim
- Low risk SSBredfish<Blim (But not in medium term)
- High risk SSBshrimp<Blim

Risk analysis with recruitment uncertainty Multispecies F candidates

- High predation pressure of cod and redfish on shrimp ⟶ only very high fishing mortality on these stocks ensure shrimp above Blim





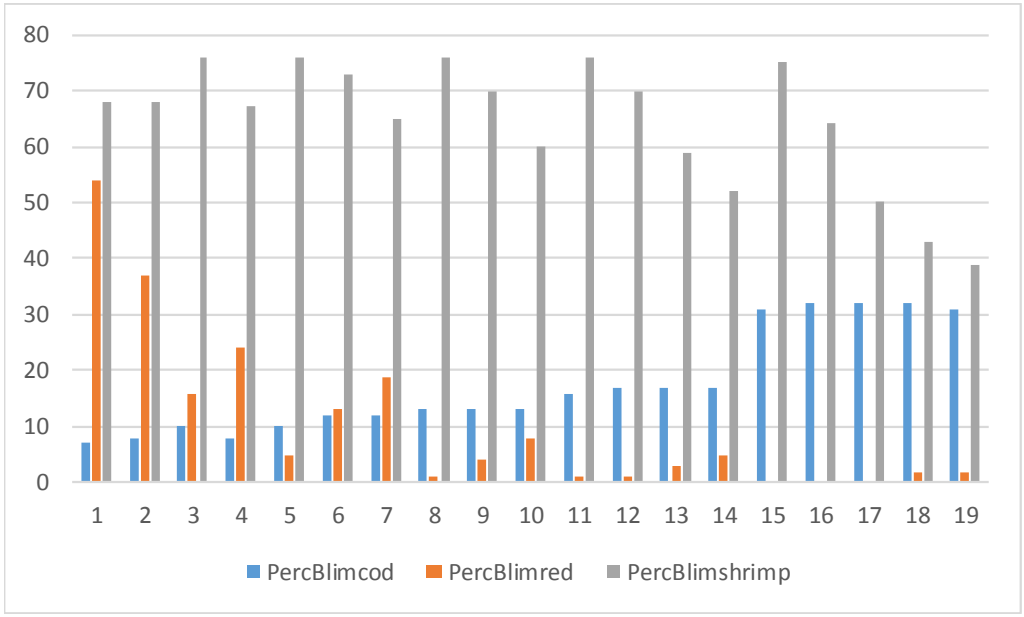
- Conclusion: The **three species cannot be maintained above Blim** at the same time.
- Next step: New **simulations disregarding each of the three stocks one by one** in terms of maintaining above Blim.

Candidate multispecies F reference values Disregarding if shrimp SSB<Blim

- Find combinations of F that ensure cod and redfish above Blim in a Deterministic way, but disregard the state of shrimp
- In **2595 out of 8000 combinations** SSBcod and SSBred were above Blim when disregarding shrimp population state.
- Selection of 19 combinations.
- In most cases when cod and redfish were well above Blim, shrimp catch was negligible ($F_{shrimp}=0$).

Criteria_code	Criteria	F_cod	F_redfish	F_shrimp
2	Disregard shrimp SSB	0.1	0	0
2	Disregard shrimp SSB	0.15	0.03	0
2	Disregard shrimp SSB	0.2	0.03	0
2	Disregard shrimp SSB	0.2	0.06	0
2	Disregard shrimp SSB	0.25	0.03	0
2	Disregard shrimp SSB	0.25	0.06	0
2	Disregard shrimp SSB	0.25	0.09	0
2	Disregard shrimp SSB	0.3	0.03	0
2	Disregard shrimp SSB	0.3	0.06	0
2	Disregard shrimp SSB	0.3	0.09	0
2	Disregard shrimp SSB	0.35	0.03	0
2	Disregard shrimp SSB	0.35	0.06	0
2	Disregard shrimp SSB	0.35	0.09	0
2	Disregard shrimp SSB	0.35	0.12	0
2	Disregard shrimp SSB	0.45	0.03	0
2	Disregard shrimp SSB	0.45	0.06	0
2	Disregard shrimp SSB	0.45	0.09	0
2	Disregard shrimp SSB	0.45	0.12	0
2	Disregard shrimp SSB	0.45	0.15	0

Risk analysis
Multispecies HCRs disregarding shrimp



Combination	Ftargetcod	Ftargetred	Ftargetshrimp
1	0.1	0	0
2	0.15	0.03	0
3	0.2	0.03	0
4	0.2	0.06	0
5	0.25	0.03	0
6	0.25	0.06	0
7	0.25	0.09	0
8	0.3	0.03	0
9	0.3	0.06	0
10	0.3	0.09	0
11	0.35	0.03	0
12	0.35	0.06	0
13	0.35	0.09	0
14	0.35	0.12	0
15	0.45	0.03	0
16	0.45	0.06	0
17	0.45	0.09	0
18	0.45	0.12	0
19	0.45	0.15	0

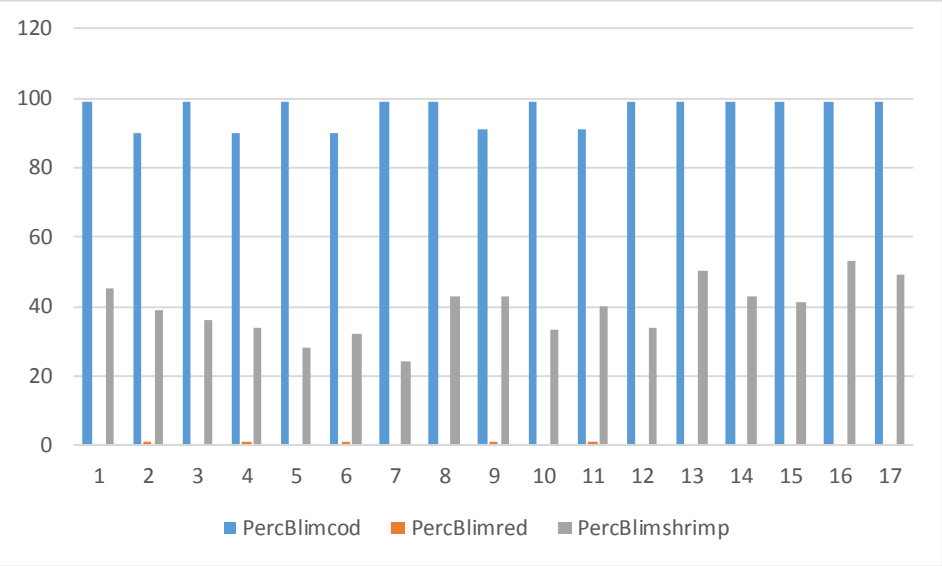
- There are a number of F combinations for cod and redfish that reduce the chance SSB being below Blim more than 10-15 percent.

Candidate multispecies F reference values Disregarding if cod SSB<Blim

- Find combinations of F that ensure shrimp and redfish above Blim in a Deterministic way, but disregard the state of cod
- In **365 out of 8000 combinations** SSBshrimp and SSBred were above Blim when disregarding cod population state.
- Selection of 17 combinations.

Criteria_code	Criteria	F_cod	F_redfish	F_shrimp
2	Disregard shrimp SSB	0.1	0	0
2	Disregard shrimp SSB	0.15	0.03	0
2	Disregard shrimp SSB	0.2	0.03	0
2	Disregard shrimp SSB	0.2	0.06	0
2	Disregard shrimp SSB	0.25	0.03	0
2	Disregard shrimp SSB	0.25	0.06	0
2	Disregard shrimp SSB	0.25	0.09	0
2	Disregard shrimp SSB	0.3	0.03	0
2	Disregard shrimp SSB	0.3	0.06	0
2	Disregard shrimp SSB	0.3	0.09	0
2	Disregard shrimp SSB	0.35	0.03	0
2	Disregard shrimp SSB	0.35	0.06	0
2	Disregard shrimp SSB	0.35	0.09	0
2	Disregard shrimp SSB	0.35	0.12	0
2	Disregard shrimp SSB	0.45	0.03	0
2	Disregard shrimp SSB	0.45	0.06	0
2	Disregard shrimp SSB	0.45	0.09	0
2	Disregard shrimp SSB	0.45	0.12	0
2	Disregard shrimp SSB	0.45	0.15	0

Risk analysis
Multispecies HCRs disregarding cod



Combination	Ftargetcod	Ftargetred	Ftargetshrimp
1	0.8	0.12	0.03
2	0.7	0.15	0.03
3	0.8	0.15	0.03
4	0.7	0.18	0.03
5	0.8	0.18	0.03
6	0.7	0.2	0.03
7	0.8	0.2	0.03
8	0.8	0.15	0.06
9	0.7	0.18	0.06
10	0.8	0.18	0.06
11	0.7	0.2	0.06
12	0.8	0.2	0.06
13	0.8	0.15	0.09
14	0.8	0.18	0.09
15	0.8	0.2	0.09
16	0.8	0.18	0.12
17	0.8	0.2	0.12

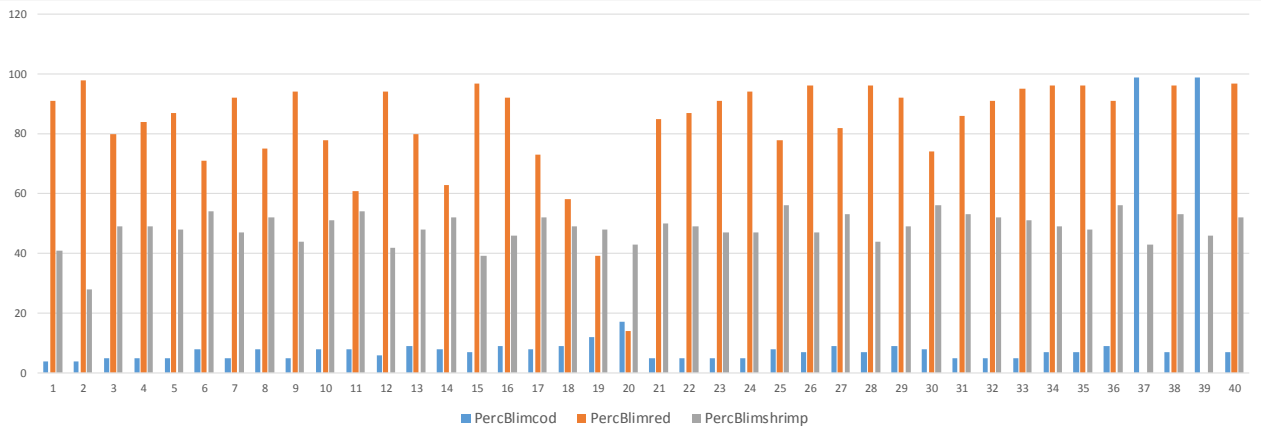
- Risk of collapse on redfish was almost null, while for cod and shrimp it was very high

Candidate multispecies F reference values Disregarding if redfish SSB<Blim

- Find combinations of F that ensure cod and shrimp above Blim in a Deterministic way, but disregard the state of redfish
- In **1068 out of 8000 combinations** SSBshrimp and SSBcod were above Blim when disregarding redfish population state.
- Selection of 40 combinations.

Criteria_code	Criteria	F_cod	F_redfish	F_shrimp
4	Disregard redfish SSB	0	0	0
4	Disregard redfish SSB	0	0.195	0
4	Disregard redfish SSB	0.05	0.03	0.03
4	Disregard redfish SSB	0.05	0.06	0.03
4	Disregard redfish SSB	0.05	0.06	0.06
4	Disregard redfish SSB	0.05	0.09	0.03
4	Disregard redfish SSB	0.05	0.09	0.06
4	Disregard redfish SSB	0.05	0.09	0.09
4	Disregard redfish SSB	0.05	0.12	0.03
4	Disregard redfish SSB	0.05	0.12	0.06
4	Disregard redfish SSB	0.05	0.12	0.09
4	Disregard redfish SSB	0.05	0.15	0.03
4	Disregard redfish SSB	0.05	0.15	0.06
4	Disregard redfish SSB	0.05	0.15	0.09
4	Disregard redfish SSB	0.05	0.2	0.03
4	Disregard redfish SSB	0.05	0.2	0.06
4	Disregard redfish SSB	0.05	0.2	0.09
4	Disregard redfish SSB	0.05	0.2	0.12
4	Disregard redfish SSB	0.05	0.3	0.03
4	Disregard redfish SSB	0.05	0.3	0.06
4	Disregard redfish SSB	0.05	0.3	0.09
4	Disregard redfish SSB	0.05	0.3	0.12
4	Disregard redfish SSB	0.1	0.09	0.03
4	Disregard redfish SSB	0.1	0.12	0.03
4	Disregard redfish SSB	0.1	0.15	0.03
4	Disregard redfish SSB	0.1	0.15	0.06
4	Disregard redfish SSB	0.1	0.2	0.03
4	Disregard redfish SSB	0.1	0.2	0.06
4	Disregard redfish SSB	0.1	0.3	0.03
4	Disregard redfish SSB	0.1	0.3	0.06
4	Disregard redfish SSB	0.1	0.3	0.09
4	Disregard redfish SSB	0.15	0.15	0.03
4	Disregard redfish SSB	0.15	0.2	0.03
4	Disregard redfish SSB	0.15	0.3	0.03
4	Disregard redfish SSB	0.15	0.3	0.06
4	Disregard redfish SSB	0.2	0.3	0.03
4	Disregard redfish SSB	0.25	0.3	0.03
4	Disregard redfish SSB	0.35	0.3	0.03
4	Disregard redfish SSB	0.75	0.25	0.105
4	Disregard redfish SSB	0.75	0.275	0.12

Risk analysis
Multispecies HCRs disregarding redfish



- Risk of collapse on cod was very low in most HCRs combinations, while for redfish and shrimp it was very high

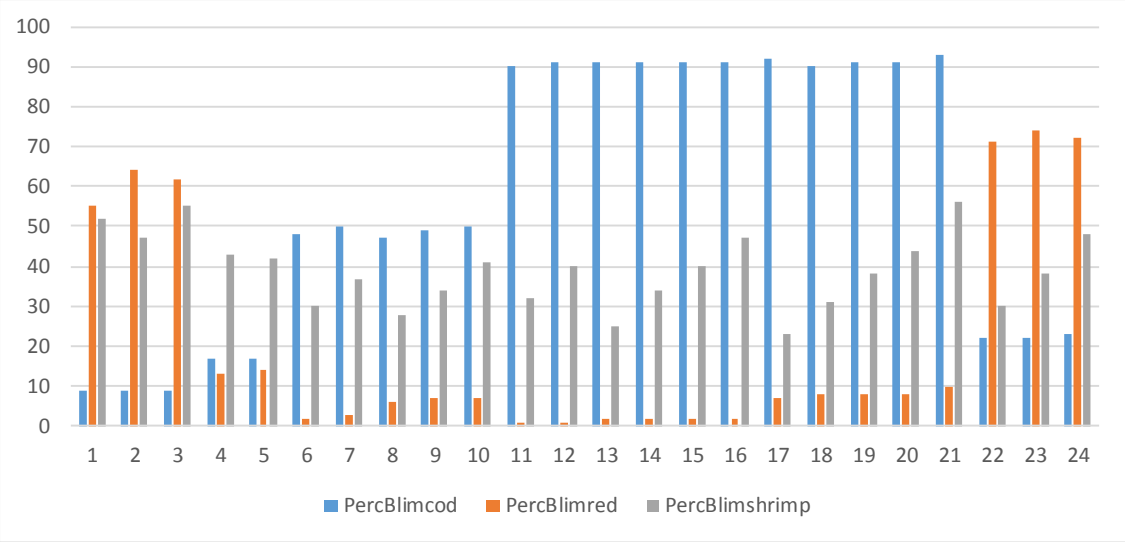
combination	Ftargetcod	Ftargetred	Ftargetshrimp
1	0	0	0
2	0	0.195	0
3	0.05	0.03	0.03
4	0.05	0.06	0.03
5	0.05	0.09	0.03
6	0.1	0.09	0.03
7	0.05	0.12	0.03
8	0.1	0.12	0.03
9	0.05	0.15	0.03
10	0.1	0.15	0.03
11	0.15	0.15	0.03
12	0.05	0.2	0.03
13	0.1	0.2	0.03
14	0.15	0.2	0.03
15	0.05	0.3	0.03
16	0.1	0.3	0.03
17	0.15	0.3	0.03
18	0.2	0.3	0.03
19	0.25	0.3	0.03
20	0.35	0.3	0.03
21	0.05	0.06	0.06
22	0.05	0.09	0.06
23	0.05	0.12	0.06
24	0.05	0.15	0.06
25	0.1	0.15	0.06
26	0.05	0.2	0.06
27	0.1	0.2	0.06
28	0.05	0.3	0.06
29	0.1	0.3	0.06
30	0.15	0.3	0.06
31	0.05	0.09	0.09
32	0.05	0.12	0.09
33	0.05	0.15	0.09
34	0.05	0.2	0.09
35	0.05	0.3	0.09
36	0.1	0.3	0.09
37	0.75	0.25	0.105
38	0.05	0.2	0.12
39	0.75	0.275	0.12
40	0.05	0.3	0.12

Candidate multispecies F reference values Disregarding if cod and redfish SSB<Blim

- Find combinations of F that ensure shrimp above Blim in a Deterministic way, but disregard the state of redfish and cod
- In **1604 out of 8000 combinations** SSBshrimp were above Blim when disregarding redfish and cod population state.
- Selection of 24 combinations.

Criteria_code	Criteria	F_cod	F_redfish	F_shrimp
5	Disregard cod and redfish SSB	0.2	0.275	0.03
5	Disregard cod and redfish SSB	0.2	0.35	0.03
5	Disregard cod and redfish SSB	0.2	0.35	0.06
5	Disregard cod and redfish SSB	0.35	0.275	0.03
5	Disregard cod and redfish SSB	0.35	0.35	0.03
5	Disregard cod and redfish SSB	0.5	0.275	0.03
5	Disregard cod and redfish SSB	0.5	0.275	0.06
5	Disregard cod and redfish SSB	0.5	0.35	0.03
5	Disregard cod and redfish SSB	0.5	0.35	0.06
5	Disregard cod and redfish SSB	0.5	0.35	0.09
5	Disregard cod and redfish SSB	0.7	0.2	0.03
5	Disregard cod and redfish SSB	0.7	0.2	0.06
5	Disregard cod and redfish SSB	0.7	0.275	0.03
5	Disregard cod and redfish SSB	0.7	0.275	0.06
5	Disregard cod and redfish SSB	0.7	0.275	0.09
5	Disregard cod and redfish SSB	0.7	0.275	0.12
5	Disregard cod and redfish SSB	0.7	0.35	0.03
5	Disregard cod and redfish SSB	0.7	0.35	0.06
5	Disregard cod and redfish SSB	0.7	0.35	0.09
5	Disregard cod and redfish SSB	0.7	0.35	0.12
5	Disregard cod and redfish SSB	0.7	0.35	0.18

Risk analysis
Multispecies HCRs disregarding cod and redfish

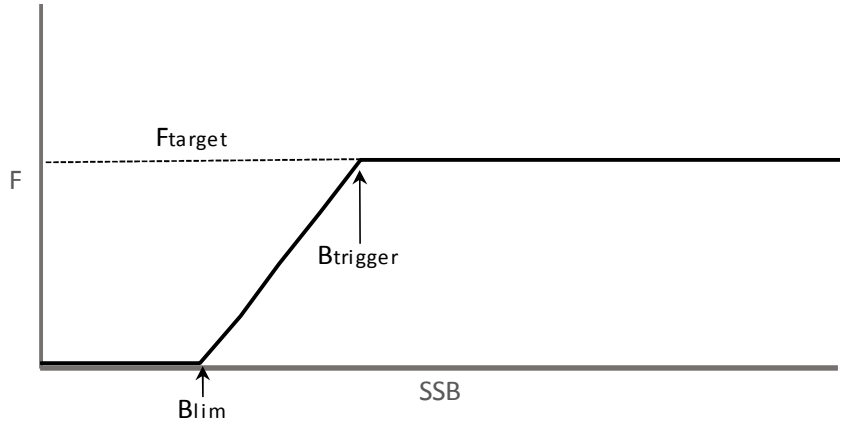


Combination	Ftargetcod	Ftargetred	Ftargetshrimp
1	0.2	0.275	0.03
2	0.2	0.35	0.03
3	0.2	0.35	0.06
4	0.35	0.275	0.03
5	0.35	0.35	0.03
6	0.5	0.275	0.03
7	0.5	0.275	0.06
8	0.5	0.35	0.03
9	0.5	0.35	0.06
10	0.5	0.35	0.09
11	0.7	0.2	0.03
12	0.7	0.2	0.06
13	0.7	0.275	0.03
14	0.7	0.275	0.06
15	0.7	0.275	0.09
16	0.7	0.275	0.12
17	0.7	0.35	0.03
18	0.7	0.35	0.06
19	0.7	0.35	0.09
20	0.7	0.35	0.12
21	0.7	0.35	0.18
22	0.4	0.5	0.03
23	0.4	0.5	0.06
24	0.4	0.5	0.09

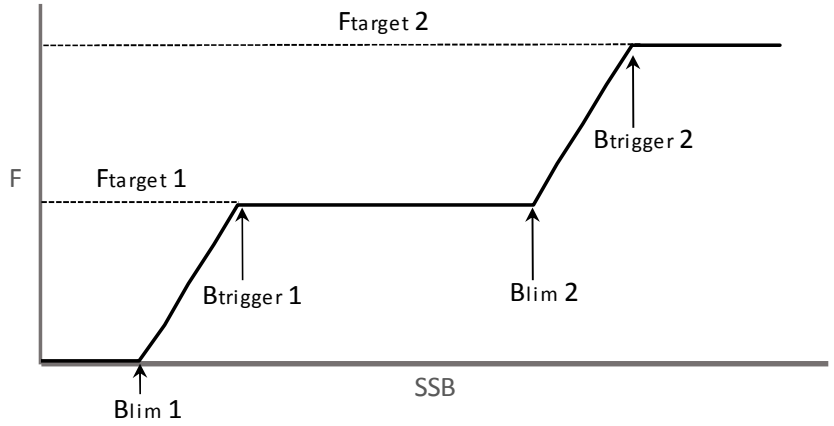
- Risk of collapse on cod and redfish showed an opposite pattern, while risk of collaps for shrimp was always high

Two stages HCR: avoid excessive predation?

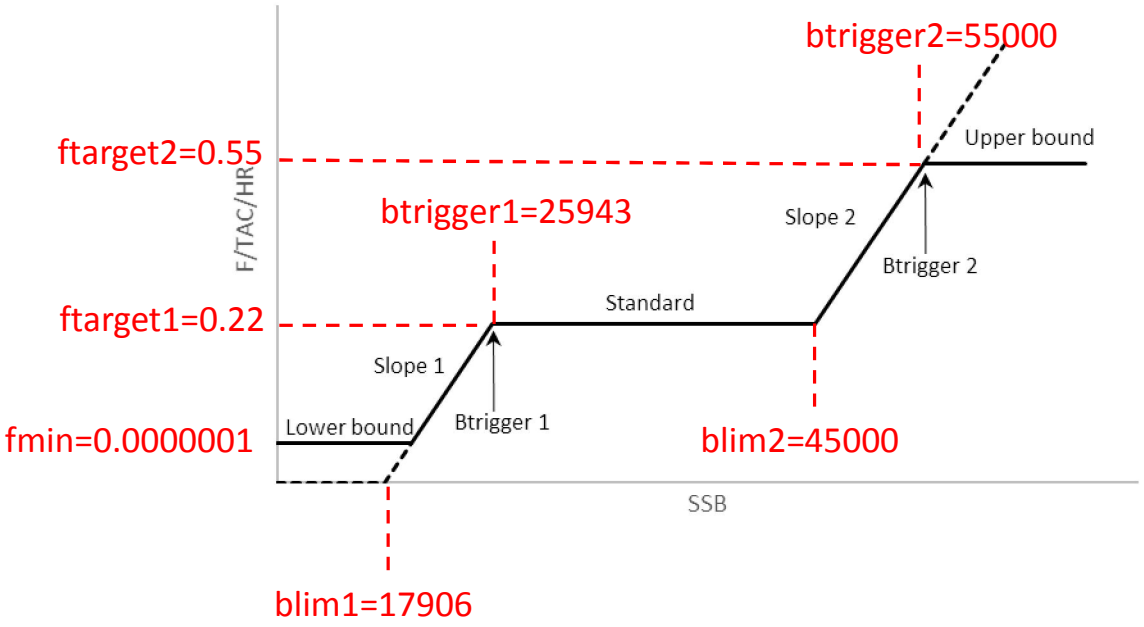
Single stage hockey stick HCR



Double stage hockey stick HCR

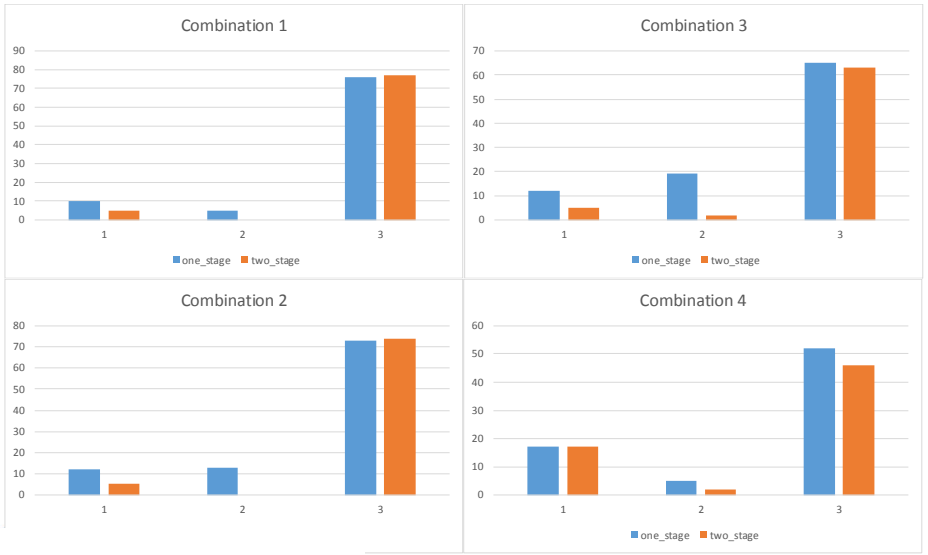


Two stages HCR: avoid excessive predation?



Two stages HCR: avoid excessive predation?

	one stage HCRs					
Combination	Ftargetcod	Ftargetred	Ftargetshrimp	PercBlimcod	PercBlimred	PercBlimshrimp
1	0.25	0.03	0	10	5	76
2	0.25	0.06	0	12	13	73
3	0.25	0.09	0	12	19	65
4	0.35	0.12	0	17	5	52
	Two stage HCRs					
Combination	Ftargetcod	Ftargetred	Ftargetshrimp	PercBlimcod	PercBlimred	PercBlimshrimp
1	0.25	0.03	0	5	0	77
2	0.25	0.06	0	5	0	74
3	0.25	0.09	0	5	2	63
4	0.35	0.12	0	17	2	46



Conclusions

- Single species F reference points were not precautionary for cod and shrimp.
- The results suggest that it is not possible having the 3 sps above Blim
- Disregarding one stock may allow finding precautionary multispecies reference points for the others.
- Precautionary HCRs for two stocks at once were only found when shrimp SSB in relation to Blim was disregarded.
- The results suggest that the two stages HCRs for cod reduces predation and increases probability of cod, redfish being above Blim.

Future improvementes

This project SC05 is not intended to provide scientific answers to be readily used for management. Instead, the main goal is developing analysis that allow starting a constructive discussion between all the stakeholders.

- Management objectives
- Improvement of the model
    - Separation beaked-golden redfish
    - Consumption models
    - Technical interactions
- Improvement of the MSE:
    - SSB-Recruitment
    - Observation and implementation errors (specially when technical interactions)

Steps to define HCRs and analyse trade-offs:

1. Multispecies model (SCO5-Task 2)
2. MSE framework (SCO5-Task 3)
3. Define HCRs (SCO5-Task 3):
    - Blim and Btrigger
    - Estimate candidate single and multispecies F reference points deterministically
    - Risk assessment of HCRs considering recruitment uncertainty and assessment error (SCO5-Task 3)
4. Analysis of economic trade-offs for a selected number of combinations of HCRs (SCO5-Task 4)