ICES WKLIFE REPORT 2012

ICES Advisory Committee

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Report of the Workshop on the Development of Assessments based on LIFE history traits and Exploitation Characteristics (WKLIFE)

13–17 February 2012

Lisbon, Portugal

ICES International Council for the Exploration of the Sea

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Executive summary

The assessment of stocks with either limited knowledge about their biology or lack of data about their exploitation levels has become increasingly problematic for ICES. Cognisant of this weakness in the current ICES' advice, this workshop was convened by ACOM to investigate the feasibility of developing a methodology for providing assessments and advice on data deficient stocks.

The **Workshop on the Development of Assessments based on LIFE history traits and exploitation characteristics (WKLIFE)**, chaired by Manuela Azevedo (Portugal) and Carl O'Brien (UK) met in Lisbon, 13–17 February 2012 to:

a) identify options for determining proxies for F_{MSY} for stocks without quantitative forecasts, using life history traits and exploitation characteristics;

b) identify methods for estimating current exploitation based on available limited information (for instance catch and survey data);

c) apply the above to the stocks in Table 1 (see Section 1 of the report for the full list of 122 stocks) and identify stocks for which this can be used and stocks for which there is insufficient information;

d) identify the data to be collected for the stocks in Table 1 in order to implement the approach under a) and b); and

e) identify options for multi-annual harvest rules for the stocks where there is sufficient information to apply the approach under a) and b).

The stocks considered at the WKLIFE meeting are the 122 stocks without quantitative forecasts that ICES provides advice for. Traditionally, these are regarded as data-poor but during discussions amongst the participants at WKLIFE it became apparent that such a designation was unhelpful and largely inaccurate. The majority of these stocks have more information available than merely either catch or landings. A categorization was proposed and adopted at the workshop. Seven categories of stock were identified – ranging from data rich through to truly data-poor. The data rich stock category is not within the remit of WKLIFE and is presented merely for completeness.

Formal calculation of F_{MSY} requires understanding of the form of a stock-recruit (S-R) relationship, or estimation with a surplus production model, and is predicated on managing a stock to ensure a specified level of recruitment. In the absence of knowledge of the S-R relationship an alternative approach of managing reproductive output can be applied, on the assumption that if sufficient reproductive output is maintained then the desired level of recruitment will follow. Such an approach was adopted by WKLIFE recognising that further work can be conducted to develop understanding of systematic relationships between spawner-per-recruit (SPR) reference points, life-history and F_{MSY}, and to develop ICES' guidelines for setting SPR reference points.

WKLIFE discussed the use of the Management Strategy Evaluation (MSE) framework to evaluate the catch rule proposed by WKFRAME3 in terms of its ability to meet maximum sustainable yield (MSY) objectives. The catch rule relies on the availability of a time-series of a survey biomass index, and combines three factors in order to provide total allowable catch (TAC) advice; namely, a survey biomass trend factor, a precautionary scale-down factor relating current biomass to a trigger level, and a factor relating current exploitation to MSY levels. The catch rule is intended to be used

in circumstances where no analytical assessment exists, so scaling to true stock size becomes a problem, and the rule relies on proxies for current stock size and MSY levels. The preliminary results do not help with the problems associated with estimating the three factors, in particular with scaling the biomass index and using suitable proxies, they do however explore the behaviour of the catch rule, both when the scaling and proxies are appropriate, and when they are not, and under scenarios representing a limited range of uncertainties. However, the main conclusions are robust: unbiased estimates of MSY/B_{MSY} (the MSY rate), exploitation rate and survey catchability are needed in order to deliver MSY targets; where a time-lag in the factor relating current exploitation to MSY levels is unavoidable, a TAC constraint is needed to stabilise the catch rule and a substantially higher risk of unintended stock depletion to low levels is evident; when applying the precautionary scale-down factor, it is better to set the biomass trigger level too high than too low. The simulation framework used to evaluate the WKFRAME3 and ANNEX IV harvest control rules presented in WKLIFE will be further evaluated after the WKLIFE meeting and the results presented to ACOM's ADGINTRO in the first week of March 2012.

WKLIFE has demonstrated that ICES should be endeavouring to move more stocks into the data-adequate category over time and further has provided a valuable insight into the challenge at hand and a way forward.

Introduction

1.1 Terms of reference

The **Workshop on the Development of Assessments based on LIFE history traits and exploitation characteristics (WKLIFE)**, chaired by Manuela Azevedo (Portugal) and Carl O'Brien (UK) met in Lisbon, 13–17 February 2012 to:

a) identify options for determining proxies for F_{MSY} for stocks without quantitative forecasts, using life history traits and exploitation characteristics;

b) identify methods for estimating current exploitation based on available limited information (for instance catch and survey data);

c) apply the above to the stocks in Table 1 and identify stocks for which this can be used and stocks for which there is insufficient information;

d) identify the data to be collected for the stocks in Table 1 in order to implement the approach under a) and b); and

e) identify options for multi-annual harvest rules for the stocks where there is sufficient information to apply the approach under a) and b).

Table 1

	code	name	EG	Section
1	cod-ewgr	Cod in ICES Subarea XIV and NAFO Subarea 1 (Greenland cod)	nwwg	2.4.1
2	smn-dp	Beaked Redfish (Sebastes mentella) in Subareas V, XII, XIV and NAFO Subareas 1+2 (Deep Pelagic stock > 500 m deep)	nwwg	2.4.10
3	smn-grl	Beaked Redfish (Sebastes mentella) in Subarea XIVb (Demersal)	nwwg	2.4.11
4	smr-5614	Golden Redfish (Sebastes marinus) in Subareas V, VI, XII and XIV	nwwg	2.4.7
5	smn-con	Beaked Redfish (Sebastes mentella) in Division Va and Subarea XIV (Icelandic Slope stock)	nwwg	2.4.8
6	smn-sp	Beaked Redfish (Sebastes mentella) in Subareas V, XII, XIV and NAFO Subareas 1+2 (Shallow Pelagic stock < 500 m deep)	nwwg	2.4.9
7	cod-coas	Cod in Subareas I and II (Norwegian coastal cod)	afwg	3.4.2
8	smn-arct	Beaked Redfish (Sebastes mentella) in Subareas I and II	afwg	3.4.5
9	smr-arct	Golden Redfish (Sebastes marinus) in Subareas I and II	afwg	3.4.6
10	ghl-arct	Greenland halibut in Subareas I and II	afwg	3.4.7
11	pan-barn	Northern shrimp (Pandalus borealis) in Subareas I and II (Barents Sea)	wgpand	3.4.9
12	cod-farb	Cod in Subdivision Vb2 (Faroe Bank)	nwwg	4.4.2
13	ple-7h-k	Plaice in Divisions VIIh-k (Southwest of Ireland)	wgcse	5.4.10
14	ple-7b-c	Plaice in Division VIIb,c (West of Ireland)	wgcse	5.4.11
15	her-nirs	Herring in Division VIIa North of 52° 30' N (Irish Sea)	hawg	5.4.15
16	her-irlw	Herring in Divisions VIa (South) and VIIb,c	hawg	5.4.17
17	spr-ech	Sprat in Divisions VIId,e	hawg	5.4.18
18	mgw-78	Megrim (Lepidorhombus whiffiagonis) in Divisions VIIb-k and VIIIa,b,d	wghmm	5.4.19

	code	name	EG	Section
19	ang-78ab	Anglerfish (Lophius piscatorius and L. budegassa) in Divisions VIIb-k and VIIIa,b,d	wghmm	5.4.20
20	cod-rock	Cod in Division VIb (Rockall)	wgcse	5.4.22
21	whg-scow	Whiting in Division VIa (West of Scotland)	wgcse	5.4.25
22	whg-rock	Whiting in Division VIb (Rockall)	wgcse	5.4.26
23	spr-celt	Sprat in the Celtic Sea and West of Scotland	hawg	5.4.28
24	ang-ivvi	Anglerfish (Lophius piscatorius and L. budegassa) in Divisions IIa, IIIa, Subarea IV and VI	wgcse	5.4.29
25	had-iris	Haddock in Division VIIa (Irish Sea)	wgcse	5.4.3
26	nop-scow	Norway pout in Division VIa	secr	5.4.31
27	san-scow	Sandeel in Division VIa	secr	5.4.32
28	nep-16	Nephrops in Division VIIb,c,j,k (Porcupine Bank, FU 16)	wgcse	5.4.34.3
29	nep-19	Nephrops in Division VIIa,g,j (South East and West of IRL, FU 19)	wgcse	5.4.34.5
30	nep-2022	Nephrops in Division VIIf,g,h (Celtic Sea, FU 20-22)	wgcse	5.4.34.6
31	sol-7h-k	Sole in Divisions VIIh-k (Southwest of Ireland)	wgcse	5.4.35
32	sol-7b-c	Sole in Division VIIb, c (West of Ireland)	wgcse	5.4.36
33	skx-67-d	Demersal elasmobranchs in the Celtic Sea and West of Scotland	wgef	5.4.37
34	meg-4a6a	Megrim (Lepidorhombus spp) in Divisions IVa and VIa	wgcse	5.4.38
35	meg-rock	Megrim (Lepidorhombus spp) in ICES Division VIb (Rockall)	wgcse	5.4.39
36	had-7b-k	Haddock in Divisions VIIb-k	wgcse	5.4.4
37	pol-celt	Pollack in Subareas VI and VII (Celtic Sea and West of Scotland)	wgcse	5.4.40
38	whg-iris	Whiting in Division VIIa (Irish Sea)	wgcse	5.4.5
39	whg-7e-k	Whiting in Division VIIe-k	wgcse	5.4.6
40	ple-iris	Plaice in Division VIIa (Irish Sea)	wgcse	5.4.7
41	ple-celt	Plaice in Divisions VIIf,g (Celtic Sea)	wgcse	5.4.8
42	nep-5	Nephrops in Division IVbc (Botney Gut - Silver Pit, FU 5)	wgnssk	6.4.14.1
43	nep-10	Nephrops in Division IVa (Noup, FU 10)	wgnssk	6.4.14.6
44	nep-32	Nephrops in Division IVa (Norwegian Deeps, FU 32)	wgnssk	6.4.14.7
45	nep-33	Nephrops in Division IVb (Off Horn Reef, FU 33)	wgnssk	6.4.14.8
46	spr-kask	Sprat in Division IIIa (Skagerrak - Kattegat)	hawg	6.4.17
47	spr-nsea	Sprat in Subarea IV (North Sea)	hawg	6.4.18
48	hom-nsea	Horse mackerel (Trachurus trachurus) in Divisions IIIa, IVb,c and VIId (North Sea stock)	wgwide	6.4.19
49	san-ns4	Sandeel in the Central Western North Sea (SA 4)	wgnssk	6.4.21.4
50	san-ns5	Sandeel in the Viking and Bergen Bank area (SA 5)	wgnssk	6.4.21.5
51	san-ns6	Sandeel in Division IIIa East (Kattegat, SA6)	wgnssk	6.4.21.6
52	san-ns7	Sandeel in the Shetland area (SA 7)	wgnssk	6.4.21.7
53	pan-flad	Northern shrimp (Pandalus borealis) in Division IVa (Fladen Ground)	wgpand	6.4.22
54	pan-sknd	Northern shrimp (Pandalus borealis) in Divisions IIIa West and IVa East (Skagerrak and Norwegian Deeps)	wgpand	6.4.23

	code	name	EG	Section
55	skx-347d	Demersal elasmobranchs in the North Sea, Skagerrak and eastern English Channel	wgef	6.4.24
56	pol-nsea	Pollack in Subarea IV and Division IIIa	wgnssk	6.4.25
57	tur-nsea	Turbot in Subarea IV and Division IIIa	wgnew	6.4.26
58	bll-nsea	Brill in Subarea IV and Divisions IIIa and VIId,e	wgnew	6.4.27
59	dab-nsea	Dab in Subarea IV and Division IIIa	wgnew	6.4.28
60	fle-nsea	Flounder in Division IIIa and Subarea IV	wgnew	6.4.29
61	lem-nsea	Lemon sole in Subarea IV and Divisions IIIa and VIId	wgnew	6.4.30
62	wit-nsea	Witch in Subarea IV, Division IIIa and VIId	wgnew	6.4.31
63	whg-kask	Whiting in Division IIIa (Skagerrak - Kattegat)	wgnssk	6.4.4
64	ple-kask	Plaice in Division IIIa (Skagerrak - Kattegat)	wgnssk	6.4.6
65	ple-eche	Plaice in Division VIId (Eastern Channel)	wgnssk	6.4.8
66	nep-25	Nephrops in North Galicia (FU 25)	wghmm	7.4.11.1
67	nep-31	Nephrops in the Cantabrian Sea (FU 31)	wghmm	7.4.11.2
68	nep-2627	Nephrops in West Galicia and North Portugal (FU 26-27)	wghmm	7.4.12.1
69	nep-2829	Nephrops in South-West and South Portugal (FU 28-29)	wghmm	7.4.12.2
70	nep-30	Nephrops in Gulf of Cadiz (FU 30)	wghmm	7.4.12.3
71	skx-89a	Demersal elasmobranchs in the Bay of Biscay and Atlantic Iberian waters	wgef	7.4.14
72	sol-8c9a	Sole in Divisions VIIIc and IXa	wghmm	7.4.15
73	ple-89a	Plaice in Subarea VIII and Division IXa	wghmm	7.4.16
74	pol-89a	Pollack in Subarea VIII and Division IXa	wghmm	7.4.17
75	whg-89a	Whiting in Subarea VIII and Division IXa	wghmm	7.4.18
76	jaa-10	Blue jack mackerel (Trachurus picturatus) in Subdivision Xa2 (Azores)	wghansa	7.4.19
77	ane-pore	Anchovy in Division IXa	wghansa	7.4.9
78	ple-2232	Plaice in Subdivisions 22 - 32 (Baltic Sea)	wgbfas	8.4.10
79	dab-2232	Dab in Subdivisions 22 - 32 (Baltic Sea)	wgbfas	8.4.11
80	tur-2232	Turbot in Subdivisions 22 - 32 (Baltic Sea)	wgbfas	8.4.12
81	bll-2232	Brill in Subdivisions 22 - 32 (Baltic Sea)	wgbfas	8.4.13
82	sal-32	Salmon in Subdivision 32 (Gulf of Finland)	wgbast	8.4.15
83	trt-bal	Sea Trout in Subdivisions 22 - 32 (Baltic Sea)	wgbast	8.4.16
84	her-31	Herring in Subdivision 31 (Bothnian Bay)	wgbfas	8.4.7
85	fle-2232	Flounder in Subdivisions 22 - 32 (Baltic Sea)	wgbfas	8.4.9
86	lin-comb	Ling (Molva molva) in the Northeast Atlantic	wgdeep	9.4.10.1
87	lin-comb	Ling (Molva molva) in the Northeast Atlantic	wgdeep	9.4.10.2
88	lin-comb	Ling (Molva molva) in the Northeast Atlantic	wgdeep	9.4.10.3
89	lin-comb	Ling (Molva molva) in the Northeast Atlantic	wgdeep	9.4.10.4
90	bli-comb	Blue ling (Molva dypterygia) in the Northeast Atlantic	wgdeep	9.4.11.1
91	bli-comb	Blue ling (Molva dypterygia) in the Northeast Atlantic	wgdeep	9.4.11.2
92	bli-comb	Blue ling (Molva dypterygia) in the Northeast Atlantic	wgdeep	9.4.11.3
93	usk-arct	Tusk in Subareas I and II (Arctic)	wgdeep	9.4.12.1
94	usk-mar	Tusk in Division XIIb (Mid Atlantic Ridge)	wgdeep	9.4.12.3
95	usk-rock	Tusk in Division Vb (Rockall)	wgdeep	9.4.12.4

	code	name	EG	Section
96	usk-oth	Tusk in Divisions IIIa, Iva, Vb, VI, VII, VIII, IX and XIIa (other areas)	wgdeep	9.4.12.5
97	arg-comb	Greater Silver Smelt (Argentina Silus) in the Northeast Atlantic	wgdeep	9.4.13.1
98	arg-comb	Greater Silver Smelt (Argentina Silus) in the Northeast Atlantic	wgdeep	9.4.13.2
99	ory-comb	Orange Roughy (Hoplostethus atlanticus) in the Northeast Atlantic	wgdeep	9.4.14
100	rng-comb	Roundnose grenadier (Coryphaenoides rupestris) in the Northeast Atlantic	wgdeep	9.4.15.1
101	rng-comb	Roundnose grenadier (Coryphaenoides rupestris) in the Northeast Atlantic	wgdeep	9.4.15.2
102	rng-comb	Roundnose grenadier (Coryphaenoides rupestris) in the Northeast Atlantic	wgdeep	9.4.15.3
103	rng-comb	Roundnose grenadier (Coryphaenoides rupestris) in the Northeast Atlantic	wgdeep	9.4.15.4
104	bsf-comb	Black scabbard fish (Aphanopus carbo) in the Northeast Atlantic	wgdeep	9.4.16.1
105	bsf-comb	Black scabbard fish (Aphanopus carbo) in the Northeast Atlantic	wgdeep	9.4.16.2
106	bsf-comb	Black scabbard fish (Aphanopus carbo) in the Northeast Atlantic	wgdeep	9.4.16.3
107	gfb-comb	Greater forkbeard (Phycis blennoides) in the Northeast Atlantic	wgdeep	9.4.17
108	alf-comb	Alfonsinos (Beryx spp.) in the Northeast Atlantic	wgdeep	9.4.18
109	sbr-comb	Red (=blackspot) seabream (Pagellus bogaraveo) in the Northeast Atlantic	wgdeep	9.4.19.1
110	sbr-comb	Red (=blackspot) seabream (Pagellus bogaraveo) in the Northeast Atlantic	wgdeep	9.4.19.2
111	sbr-comb	Red (=blackspot) seabream (Pagellus bogaraveo) in the Northeast Atlantic	wgdeep	9.4.19.3
112	cyo-nea	Portuguese dogfish (Centroscymnus coelolepis) and leafscale gulper shark (Centrophorus squamosus) in the Northeast Atlantic	wgef	9.4.20
113	sck-nea	Kitefin shark (Dalatias licha) in the Northeast Atlantic	wgef	9.4.21
114	dgs-nea	Spurdog (Squalus acanthias) in the Northeast Atlantic	wgef	9.4.6
115	por-nea	Porbeagle (Lamna nasus) in the Northeast Atlantic	wgef	9.4.7
116	bsk-nea	Basking shark (Cetorhinus maximus) in the Northeast Atlantic	wgef	9.4.8
~~117~~	~~eel-eur~~	~~European eel~~	~~wgeel~~	~~9.4.9~~
118	bss-comb	European seabass in the Northeast Atlantic	wgnew	9.4.23
119	~~czs~~gur-comb	~~Spiny~~ red gurnard in the Northeast Atlantic	wgnew	9.4.24
120	gug-comb	Grey gurnard in the Northeast Atlantic	wgnew	9.4.25
121	mut-comb	Striped red mullet in the Northeast Atlantic	wgnew	9.4.26
122	boc-nea	Boarfish in the Northeast Atlantic	wgwide	9.4.22

WKLIFE will report by 5th March 2012 for the attention of ACOM.

The stocks listed in Table 1 were discussed within WKLIFE noting two issues:

- There was a misunderstanding by ICES last year about the common name of *Aspitrigla cuculus*. During last year's advice drafting within the ICES' Secretariat, this species was initially named as *spiny red gurnard* and subsequently, during ICES' ADGWIDE it was correctly renamed as *red gurnard*. The species code will be corrected in the future by ICES to GUR, following the FAO code convention and has been amended in Table 1 (row 119).
- ICES does not have an accepted time-series of stock wide catch for eel and consequently, eel will not be considered further by WKLIFE (Table 1 – row 117 deleted).

1.2 Background

The main issue addressed by the ToRs of the WKLIFE meeting relates to the assessment of stocks with either limited knowledge about their biology or lack of data about their exploitation levels. Cognisant of this weakness in the current ICES' advice, this workshop was convened by ACOM to investigate the feasibility of developing a methodology for providing advice on data deficient stocks.

1.3 Special request on cod stocks in Greenland Waters

ICES received a special request from Greenland in advance of the ICES' WKLIFE meeting. The background, justification and request are presented below.

1.3.1 Background

For Cod in ICES Subarea XIV and NAFO Subarea 1 (Greenlandic cod) ICES has in the past 20 years advised that no fishery or similar should take place based on the ceased fishery since the early 1990s and low stock and recruitment indices from surveys. With the implementation of the Precautionary Approach in the 1990s and recently the MSY framework in the ICES advisory system, various justifications have formed the basis for principally the same advice, namely zero catch. In the recent decade a number of strong year-classes of cod have been observed in Greenland waters, and these year-classes have to some extent resulted in an increase in adult biomass, although not in the expected increase. Despite these optimistic stock trends, ICES has kept its zero catch advice. The Greenland fishing industry and the Government of Greenland both have difficulties in interpreting the basis for the advice and also in understanding the necessary criteria that could allow for an opening of the fishery.

1.3.2 Justification

For the cod stocks there is presently no analytical assessment and no reference points are defined for the stock. In the past ICES has advised that no fishery should take place due to low stock size. In the absence of an analytical assessment the stock size is measured by means of surveys that provide relative indices. So far, the survey indices have not been a sufficient basis for estimation of reference points.

In order to implement measures that will allow the stock to rebuild it is necessary to have further guidance on the estimation of reference points given the present assessment methodology. Also any biomass limit points that are the basis for the present advice must be quantified in order to justify an opening of the fishery.

Therefore, ICES should estimate or suggest ways forward to achieve reference points that will provide a basis for a sound management of the stock. These estimates or methodologies should *be based on the assumption that the present data for assessment will remain the same as they presently are.*

The cod fishery in Greenland is targeting more stocks: offshore cod with Icelandic origin, offshore cod from offshore Greenland spawning grounds and inshore cod having their origin at local spawning populations. In the coastal areas all stocks are mixed in the fisheries. It is therefore vital for a sound management to have stock separated advice.

1.3.3 Request

Given the present status of the cod stocks in Greenland and that no reference points have yet been defined:

1. *ICES is requested to estimate or to provide guidelines for estimation of reference points for cod in ICES Subarea XIV and NAFO Subarea 1 (Greenlandic cod) including limit reference points or other estimates that are presently used to distinguish between a zero advice and an advice of reopening the fisheries.*

2. *ICES is requested to provide separate advice for the offshore stocks in ICES Subarea XIV and NAFO Subarea 1, and for the inshore fjord stocks in NAFO Subarea 1.*

WKLIFE only considered the first of these two requests and provides guidance for the ICES' NWWG in Section 5.4.1.

1.4 Conduct of the meeting

The agenda for the meeting is presented in Annex A.

Two working documents were presented at WKLIFE:

WD1:

Martell, S. and Froese, R. A simple method for estimating MSY from catch and resilience.

WD2:

De Oliveira, J., Darby, C., Fernández, C. and O'Brien, C. Evaluation of WKFRAME3 catch rule.

For completeness and ease of reference, WD2 is reproduced in the Annex D to this report and a brief description of the method presented in WD1 is described in Section 2.2.

1.5 Structure of the report

The structure of the report is as follows:

- general introduction, terms of reference, background and the follow-up process within ICES in Section 1;
- generic scientific considerations for stocks without quantitative forecasts in Section 2;
- investigation of the stocks without quantitative forecasts assessed by ICES' WGDEEP, WGEF and WGNEW in Section 3;
- investigation of the stocks without quantitative forecasts assessed by ICES' WGNSSK, WGCSE and WGHMM in Section 4;

- investigation of the stocks without quantitative forecasts assessed by ICES' NWWG, AFWG, HAWG, WGWIDE, WGHANSA, WGBFAS and WGBAST in Section 5;
- multi-annual harvest rules in Section 6;
- discussion and conclusions in Section 7; and
- references are collated in Section 8.

1.6 Follow-up process within ICES

The simulation framework used to evaluate the WKFRAME3 and ANNEX IV harvest control rules presented and discussed in WKLIFE will be used to evaluate the utility of advice based on categories 3 – 5 (see Sections 2.5.3 – 2.5.5) as outlined in the later Section 6. The simulations will be undertaken after the WKLIFE meeting and the results presented to ACOM's ADGINTRO in the first week of March 2012.

In addition, Greenland requested ICES to "provide separate advice for the offshore stocks in ICES Subarea XIV and NAFO Subarea 1, and for the inshore fjord stocks in NAFO Subarea 1." This request will be addressed by NWWG in April 2012.

2 Generic scientific considerations for stocks without quantitative forecasts

2.1 Predicting fisheries reference points with minimal data

2.1.1 Life-history based per-recruit reference points

Formal calculation of F_{MSY} requires understanding of the form of a stock-recruit (S-R) relationship, or estimation with an age-aggregated surplus production model, and is predicated on managing a stock to ensure a specified level of recruitment or surplus production. In the absence of knowledge of the S-R relationship or surplus production an alternative approach of managing reproductive output can be applied, on the assumption that if sufficient reproductive output is maintained then the desired level of recruitment will follow.

Age-structured per-recruit models follow cohort progression and can provide outputs of yield-per-recruit and spawning stock biomass-per-recruit. Per-recruit models do not require any knowledge of S-R relationships and are parameterised with life-history information; together with information of selectivity (partial recruitment) with respect to the fishery.

YPR_{max} is the maximum YPR that can be achieve for a given selection pattern and irrespective of reproductive output. This is achieved by fishing at F_{max}, beyond this level a stock would be considered to be growth-over-fished. However, owing to concerns that fishing at F_{max} is likely to lead to recruit limitation (Deriso 1982) a variety of other reference levels have been suggested. This includes $F_{0.1}$ (the fishing mortality at the point of the YPR curve that is 10% of the gradient at the origin, Sissenwine & Shepherd (1987)) and SPR based reference points. SPR based reference points are based on maintaining a specific level of reproductive output on the assumption that on average this will lead to high levels of recruitment. The question of how much spawning per recruit is enough has been examined in a variety of empirical (e.g. Mace and Sissenwine, 1993) and theoretical studies (e.g. Clark 1991, Mace 1994, Walters & Kitchell 2001, Clark 2002, Williams & Shertzer 2003) and have typically concluded that maintaining 30-40% SPR can lead to high levels of sustainable yield from most widespread demersal stocks. The actual levels of SPR required to avoid recruit limitation will vary between stocks and species and can vary through time. Information to date suggests that SPR reference levels may show systematic variation with species L_{inf} and taxonomy (e.g. Mace & Sissenwine 1993) or reproductive mode, and that SPR reference levels may be inversely correlated with L_{max}. Further work can be conducted to develop understanding of systematic relationships between SPR reference points and life-history, and to develop ICES' guidelines for setting SPR reference points.

Can YPR, or SPR reference points be considered as proxies for MSY? Or are they simply reference points to achieve SY (Sustainable Yield)? If SPR reference levels are considered to be the minimum level of reproductive output that is required to avoid recruit limitation (albeit allowing for a precautionary buffer to account for uncertainty), then SPR reference levels and associated F values that generate the maximum YPR whilst maintaining the required level of SPR can be considered direct proxies for F_{MSY}. Therefore F_{SPR} and SPR reference levels designated to maximise yield whilst maintaining reproductive output can be considered appropriate reference points for indicators applied under the MSFD Descriptor 3 for criterion 3.1 (Level of pressure of the fishing activity) and criterion 3.2 (Reproductive capacity of the stock) respectively.

2.1.2 Data-poor methods to establish per-recruit models

The ultimate information required to set up an age-structured per-recruit model is a schedule of M at age, maturity at age, weight at age and selection at age of the fishery. In many cases these parameters are known directly for a stock of interest; however where these parameters are not known directly they can be derived using a variety of techniques. Understanding of life-history relationships have demonstrated that the main required parameters (excluding selectivity) can be calculated on the basis of very limited life-history information for the stock in interest.

Theory and empirical observations demonstrate that life-history traits, such as growth, L_{inf} and L_{Mat} are related within and among species (Charnov 1993, Frisk et al 2001, Gislason et al 2008, Jensen 1996). A number of these relationships have been formulated thereby allowing unknown life-history parameters to be predicted for species from readily available parameters such as L_{inf} or L_{max}. Le Quesne & Jennings (2012) used the relationship between L_{max} and other life-history parameters to parameterise per-recruit models for fish species based solely on the species L_{max} and whether they are teleosts or elasmobranchs. This model was then used to calculate yield-per-recruit (YPR) and spawner-per-recruit (SPR) reference points for 124 species in the Celtic Sea demersal fish community as part of a vulnerability risk assessment of the potential impacts of fishing on biodiversity (Le Quesne & Jennings 2012). The only information for a per-recruit analysis that cannot be derived from life-history theory is the selectivity pattern of the fishery; in the case of the Celtic Sea fish assessment Le Quesne & Jennings assumed knife-edge recruitment to the fishery at age 1. (A full description of the method is provided in Le Quesne & Jennings 2012.) Such as simplified assumption regarding selectivity would likely be challenged in providing stock assessment advice and further necessitate a justification.

The generic life-history model was applied to the stocks covered in the ToRs on the basis of L_{inf} or L_{max}, where L_{inf} was used preferentially if available, and YPR and SPR reference points calculated under the assumption of knife-edge recruitment to the fishery age 1 and age 2 . The reference points calculated for the WKLIFE stocks used the same life-history relationships as Le Quesne & Jennings (2012), apart from the Von Bertalanffy K-L_{inf} relationship which was taken from Gislason et al (2008, Table 1 – all species). The relationships used to calculate these reference points are presented in Table 2.1.2.1.

The life-history model implies that for a given selection pattern YPR and SPR reference points are related to species L_{max}, or L_{inf}; however the reference points are sensitive to the assumed selection pattern (Figure 2.1.2.1). There is no basis for defining the selection pattern on the basis of life-history theory so it would be important to have stock or fishery specific selectivity patterns whenever they are available.

A number of caveats should be noted when applying the life-history model. Firstly the relationships can only be applied to species with an L_{max} from 20-270cm (Le Quesne & Jennings 2012); beyond these limits the relationships break down and cannot generate plausible life histories, particular caution should be applied for species with L_{max} approaching these limits. For species with an L_{max} greater than 270cm the reference points for 270cm were applied. Secondly, the empirical life-history relationships were calculated predominantly for observations of temperate shelf species and therefore may not be applicable to species that do not live in these regions such as deepwater species. Furthermore when the reference points were being generated the maximum possible observation was limited to an upper value of 2 yr^{-1}.

The application of the generic life-history model to the WKLIFE stocks was to demonstrate that F reference points can be generated for data poor stocks on the basis of very limited life-history data. The life-history model was developed for the purposes of ranking species in risk assessments; the accuracy of the specific reference points generated has not been rigorously evaluated. Although the life-history relationships can generate all the required parameters (except selectivity) to create a per-recruit model it would be preferable to use stock or species specific data to parameterise per-recruit models whenever they are available. A preliminary visual comparison of F reference points calculated from life-history relationships and stock-specific data used by ICES working groups was conducted (Figure 2.1.2.1)

The life-history relationships used to derive parameters for data-poor stocks in this study were based on L_{max} or L_{inf}. The relationships could be reformulated to allow the parameters to be derived from length at 50% maturity as this parameter may be more regularly, and accurately, defined than L_{max} or L_{inf}. The model may be extended further in the future by including information about how different reproductive strategies (e.g. determinate, indeterminate, viviparous) or habitat related differences in recruitment variability (Spencer & Collie 1997) may be used to increase the usefulness of per recruit based reference points.

Function	Unit	Relationship	Source
Asymptotic length equation 5	cm	$Log_{10}(L_\infty) = 0.044 + 0.9841 \times Log_{10}(L_{max})$	Froese & Binohlan (2000)
Weight tion 14	g	$W_t = 0.01 \times L_t^3$	Gislason *et al.* (2008) equa-
Natural mortality rate tion 2	year^{-1}	$M_t = \exp(0.55 - 1.61 \times \ln(L_t) + 1.44$	Gislason *et al.* (2010) equa-
		$\times \ln(L_\infty) + \ln(k))$	
Teleosts			
Von Bertalanffy K all species	year^{-1}	$K = 2.15 \times L_\infty^{-0.46}$	Gislason *et al.* (2008) Table 1
Length at first maturity for demersal species	cm	$L_{mat} = 0.64 \times L_\infty^{0.95}$	Gislason *et al.* (2008) Table 1
Elasmobranchs			
Von Bertalanffy K caption for Fig. 6	year^{-1}	$K = -0.17 \times \ln(L_{max}) + 0.97$	Frisk *et al.* (2001) equation in
Length at first maturity caption for Fig. 1	cm	L_{mat} $0.7 \times L_{max} + 3.29$	Frisk *et al.* (2001) equation in

Table 2.1.2.1. Life-history relationships used to parameterise the per-recruit models from L_{inf} or L_{max}.

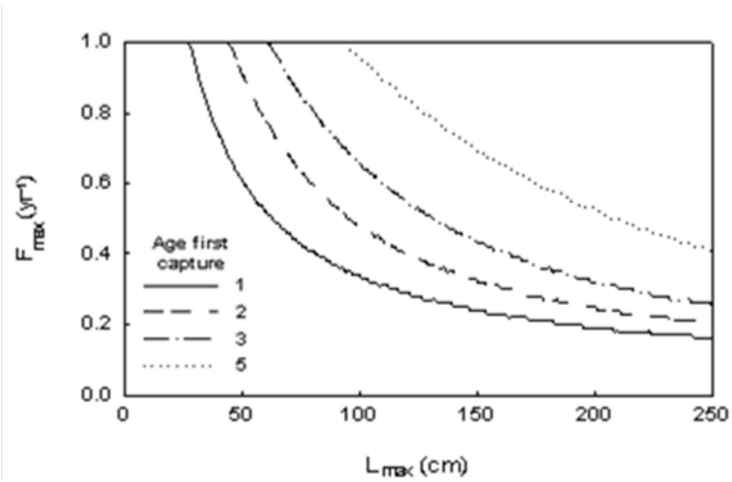

Figure 2.1.2.1. Variation in teleost F_{max} with length for a range of age of first capture.

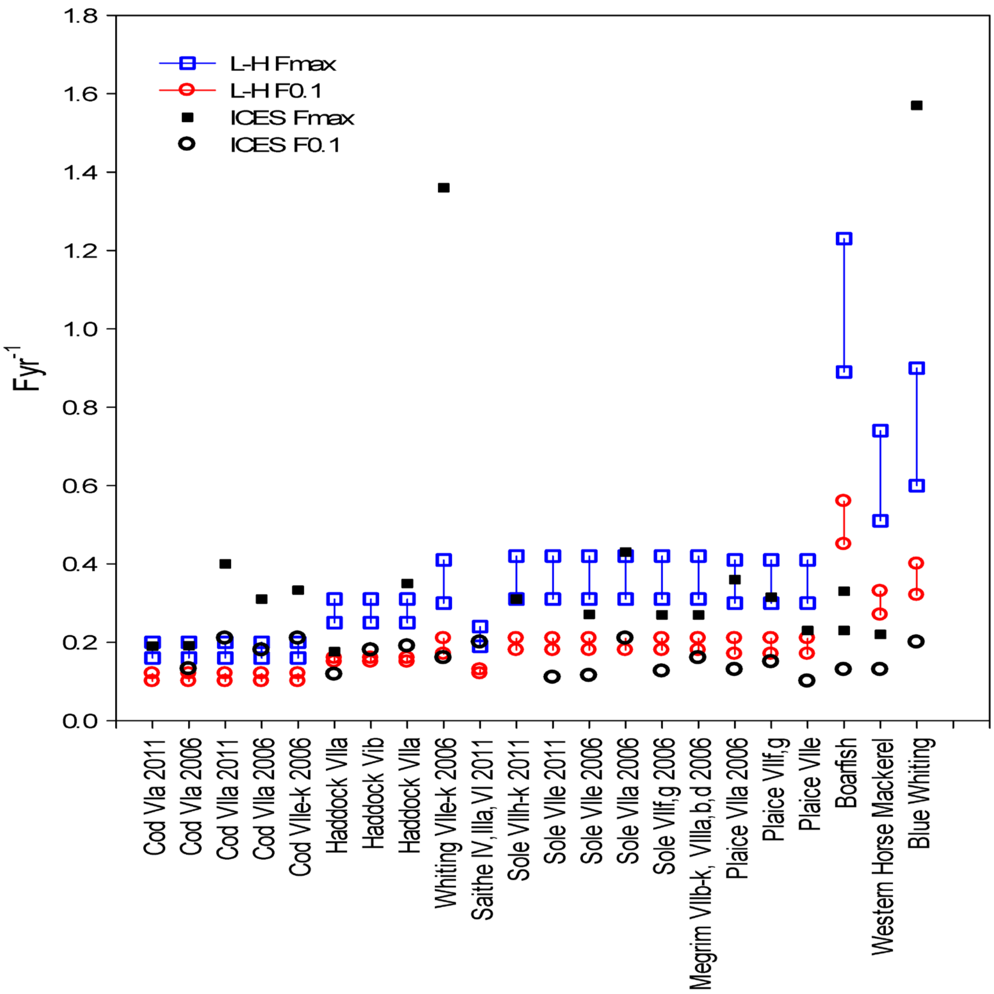

Figure 2.1.2.1. Comparison of YPR reference points from ICES advice and the reference points calculated using life-history invariants. The life-history based reference points used relationships presented in Le Quesne & Jennings (2012), apart from the L_{inf}-K relationships that was taken from Gislason *et al.* (2008), the calculations used the Celtic Sea L_{max} values presented in Le Quesne & Jennings (2012), and were calculated with knife-edge recruitment at age 1 and age 2.

2.2 Estimating MSY from catch and resilience

In WD1, Martell and Froese (submitted) propose a new method for estimating maximum sustainable yield (*MSY*) from a time-series of catch data, resilience of the species, and estimations about depletion, i.e. relative stock abundances at the beginning and the end of the time series. The Appendix from their paper, which describes the Catch-MSY method, is summarised in Section 2.2.2. The R-source code of the method was made available at the WKLIFE workshop in order to investigate simple stock assessment and harvest control procedures for data-poor stocks.

2.2.1 Outline of the Catch-MSY method

The simplest model-based methods for estimating *MSY* are production models such as the Schaefer model (1954). At a minimum these models require time-series data of abundance and removals to estimate two model parameters: the carrying capacity *k* and the maximum rate of population increase *r* for a given stock in a given ecosystem. Given only a time-series of removals (and assumptions regarding start and end biomasses as a function of k), a surprisingly narrow range of *r*-*k* combinations is able to maintain the population such that it neither collapses nor exceeds the assumed carrying capacity. Possible *r-k* combinations can be restrained further by adding estimations of relative population sizes at the beginning and end of the time-series, effectively adding stock-depletion information to the analysis. The set of viable *r-k* combinations can be used to approximate *MSY*.

Section 2.2.2 provides a more detailed description and relevant equations.

2.2.2 Catch-MSY method

The Catch-MSY method outline here for approximating *MSY* is based on a very simple Schaefer production model, and it should be noted here that other models with alternative assumptions about the form of the stock productivity relationship could be substituted with the additional structural assumptions. The primary objectives of this method are 1) to devise a very simple method that can be applied to any catch time series, 2) the method must be easy to understand and implement so that it can be used my many people involved in fisheries science and management, and 3) the method requires few additional assumptions.

The minimum data requirement is a catch time series from a specific area that is normally defined as a unit stock where the population is closed to immigration and emigration (Table 2.2.2.1, equation 1). In addition to the catch data, the initial depletion level and a range of current depletion levels (i.e., the current stock size relative to the unfished carrying capacity) must also be specified, these are denoted by λ_0 for the initial stock size and by λ_1 and λ_2 for the final lower and upper limits, respectively. The last remaining assumption is to specify the standard deviation in the process errors σ_v; process errors are assumed lognormal, independent, and identically distributed (10). If $\sigma_v = 0$, this is equivalent to assuming a deterministic model. The model parameters (4) of interests are the carrying capacity *k* and the maximum intrinsic rate of population growth *r*. Starting with an assumed relative biomass of $B1 = \lambda_0\, k$ in the first year, biomass in subsequent years is calculated based on (6), where the observed catch is subtracted from the start of the year biomass. This assumes the catch is measured without error, unless $\sigma_v > 0$.

A very simple importance sampling procedure is then used to map the joint distribution of model parameters (in this case, *r* and *k* of the Schaefer production model) that lead to current depletion levels between λ_1 and λ_2. In cases where combinations of (*r*, *k*) lead to the population going extinct or overshooting *k* before the end of the time series, we simply assign a 0 for that parameter combination. For combinations of (*r*, *k*) that result in final stock sizes between λ_1 and λ_2 we assign a value of 1 (equation 7). Then for each parameter combination that results in a viable population at the end of the time series, estimates of *MSY* can be calculated from the population parameters (11).

The basic algorithm is implemented as follows:

1. Specify the initial status of the stock (λ_0) and lower (λ_1) and upper (λ_2) limits of the final status of the stock (e.g., values of $\lambda_0 = 0.5$ imply that the stock was at half of carrying capacity at the beginning of the time series and $\lambda_1 = 0$ and $\lambda_2 = 1$ imply that the stock is somewhere between completely depleted and at its carrying capacity at the end). Also specify σ_v to a value greater than 0 if you wish to include a stochastic component.
2. Draw a trial parameter set Θ_i from the respective prior distributions (e.g., equations 8, 9, and 10).
3. Initialize the population model at the trial value of k_i (5).

4. Update the biomass next year using the Schaefer production model (6).
5. Calculate the likelihood of the parameter vector Θ_i using (7).
6. Repeat steps 2-5 many times (e.g., 100,000) and store the 0 or 1 likelihood for each trial.
7. Plot distributions of management quantities (11) only for cases in which the likelihood is 1.

Table 2.2.2.1. A simple Schaefer production model and the corresponding management parameters.

Data		
c_t observed catch from $t = 1$ to $t = n$ years λ_0 depletion level in year 1 λ_1, λ_2 lower and upper bounds for depletion level σv process error standard deviation		(1) (2) (3)
Parameters		
$\Theta = \{k, r\}$		(4)
Initial states $t = 1$		
$B_t = \lambda_0\, k \exp(\nu\ t)$		(5)
Dynamic states $t > 1$		
$B_{n+1} = [B_t + r\ B_t(1 - B_t/k) - c_t] \exp(\nu\ t)$		(6)
Likelihood		
$l(\Theta \mid c_t) = 1$ $= 0$	$\lambda_1 \leq B_{n+1}/k \leq \lambda_2$ $\lambda_1 > B_{n+1}/k > \lambda_2$	(7)
Prior densities		
$p(\log(k)) \sim \text{uniform}(\log(l\ k), \log(u\ k))$ $p(\log(r)) \sim \text{uniform}(\log(l\ r), \log(u\ r))$ $p(\nu\ t) \sim \text{normal}(0, \sigma v)$		(8) (9) (10)
Management quantities		
$MSY = ¼\ r\ k$ $B_{msy} = ½\ k$ $F_{msy} = ½\ r$		(11)

2.3 Life-history simulator

2.3.1 The gislasim() function in FLR

The FLR Core Team developed two new functions within FLR (FLAdvice package) that allow the simulation of a fish stock based on life history parameters. In brief, the *gislasim()* function constructs from a value of maximum length (Linbf) a complete set of parameters for the corresponding growth model (von Bertalanffy) and maturity function, all based on the life-history relationships derived by Gislason (2008), and assumed selectivity function. This set of parameters can then be altered with extra information on the specific stock, and it is then passed on the *lh()* function, which generates the corresponding reference points and population structure in equilibirum according to a set of relationships between life history and natural mortality, maturity, and weight at age. A stock recruitment relationship, parameterized in terms of steepness and virgin biomass is used. Both parameters must be provided, the later providing a scaling factor for the resulting population in terms of total biomass. The resulting object, of class FLBRP, contains a set of biological reference points ($F_{0.1}$, F_{msy}, F_{max}, F_{crash}), a matrix of abundances at age at equilibrium for different levels of exploitation (between 0 and F_{crash}). This can then be used to generate a simulated population by projecting under a given scenario of fishing mortality.

2.4 Risk assessment and PSA

Often, it may be necessary to make an assessment of the relative risk which fishing poses to ecosystem components in a semi-quantitative manner. Methods are designed to use known features of the life-history characteristics and expert judgement in order to prioritise where to focus further more quantitative assessments. The generic term for the techniques is the Ecological Risk Assessment of the EFfects (ERAEF). Hobday *et al*. (2007) describe the technique as originally evolved and Cotter & Lart (2010) give an overview of these methods and reviews their use around the world. Risks from fishing activities on components of the ecosystem are examined through expert judgment at increasing levels of quantitative analysis in relation to the risk assessed.

Productivity and Susceptibility Analysis (PSA) can be carried out on stocks, stock proxies and habitats affected by fishing activities. Productivity is scored using such attributes as growth, maximum age, maximum size, fecundity and reproductive strategy. High risk attributes, such as slow growth and low fecundity, score more highly in terms of risk. Susceptibility is related to the catchability part of fishing mortality rather than the effort part and is derived from scoring attributes such as the geographical availability of the stock to the fishery, whether the stock is likely to encounter the gear, and scores for selection and survival post encounter (Figure 2.4.1. in ICES WKFRAME3 (ICES, 2012)).

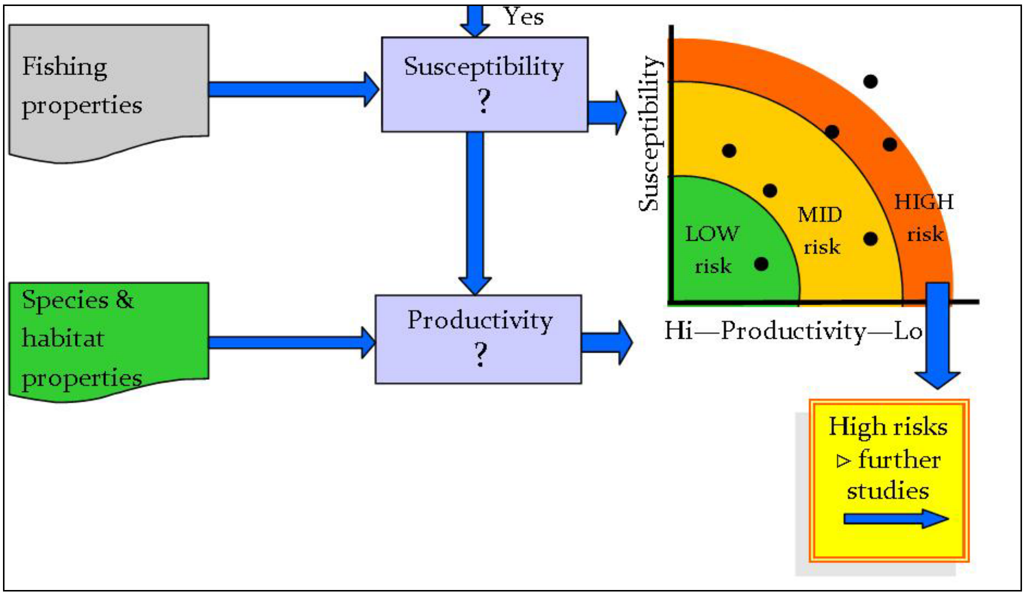

Figure 2.4.1. Illustration of Productivity and Susceptibility analysis; modified from Cotter and Lart (2011). Each point on the graph represents a stock or stock proxy affected by fishing. Note; Productivity is plotted from high to low on the horizontal axis (hence from low risk to high risk, when moving from left to right on the horizontal axis); Susceptibility from low to high on the vertical axis (hence from low risk to high risk, when moving upwards on the vertical axis). A similar process may be undertaken for habitats on a separate plot. Those in the top right hand section of the graph (highest Euclidean distance from the origin) represent components at highest risk due to the effects of fishing and, therefore, should be prioritised for further analysis.

There are a number of scoring schemes available (Cotter & Lart 2011), and ideally the attributes scored should be as independent from each other as possible to maximise the amount of information drawn on. Use of these schemes would require agreement on the attributes and scoring. To make the assessment as precautionary as possible, where the score for an attribute is unknown a default high risk level is scored.

However, it should not be forgotten that such an approach (PSA) will not provide reference points but can indicate high risk cases that require special attention.

2.5 Generic categorization of stocks by WKLIFE

The stocks considered at the WKLIFE meeting are the 122 stocks without quantitative forecasts that ICES provides advice for. Traditionally, these are regarded as data-poor but during discussions amongst the participants at WKLIFE it became apparent that such a designation was unhelpful and largely inaccurate.

The majority of these stocks have more information available than merely either catch or landings. A categorization was proposed and adopted at the workshop. Seven categories of stock were identified – ranging from data rich through to truly data-poor. The data rich stock category is not within the remit of WKLIFE and is presented merely for completeness.

2.5.1 Category 1 – data rich stocks (quantitative assessments)

This category includes stocks with full analytical assessments and forecasts; e.g. North Sea cod.

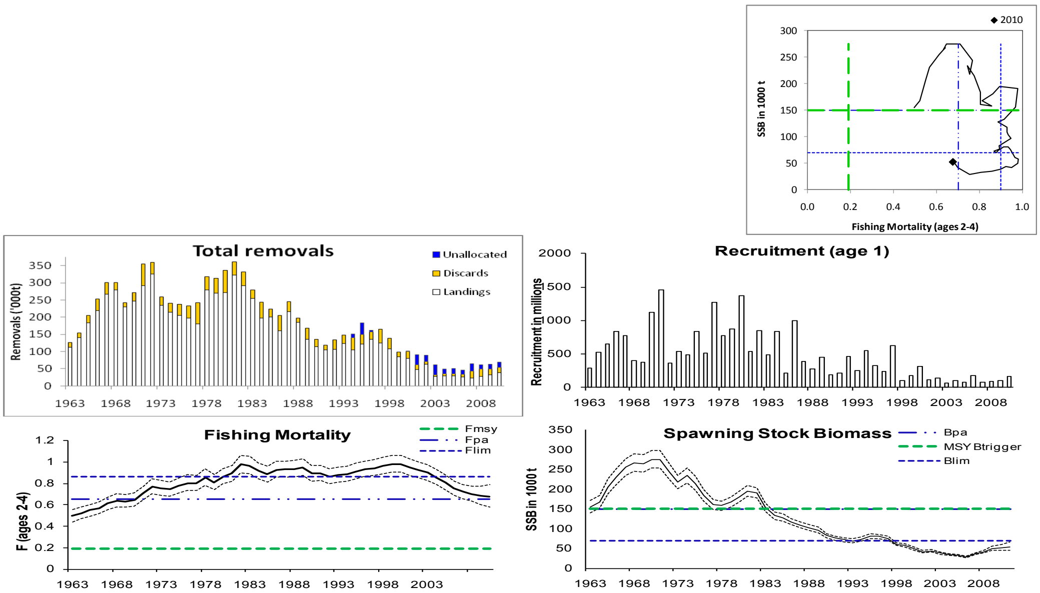

Figure 2.5.1.1. Cod in Subarea IV (North Sea) and Divisions VIId (Eastern Channel) and IIIa West (Skagerrak). Summary of stock assessment with point-wise 95% confidence intervals, catch estimated, and adjusted for unallocated removals (from 1993). Weights in tonnes.

2.5.2 Category 2 – negligible landings stocks

This category includes stocks where landings are negligible in comparison to discards; e.g. Irish Sea whiting.

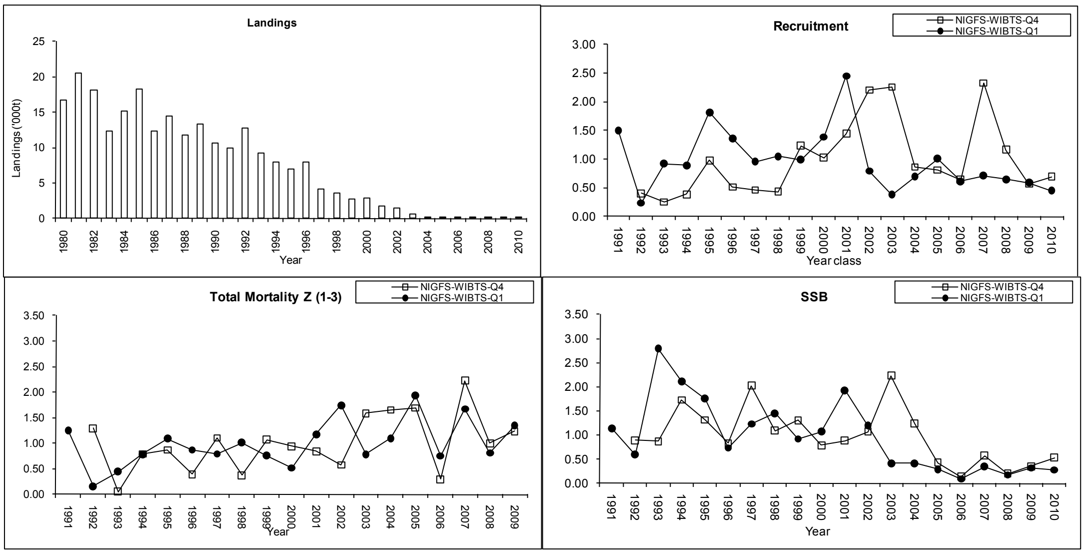

Figure 2.5.2.1. Whiting in Division VIIa (Irish Sea). Landings reported to the WG (in thousand tonnes, 1991-2002 estimates include sampled-based estimates of landings at a number of Irish Sea ports), and mean standardised: SSB, total mortality (Z), and recruitment estimates, from single fleet SURBA analysis.

2.5.3 Category 3 – stocks with analytical assessments and forecasts that are only treated qualitatively

This category includes stocks with quantitative assessments and forecasts which for a variety of reasons are merely indicative of trends in fishing mortality, recruitment and biomass; e.g. Eastern Channel plaice.

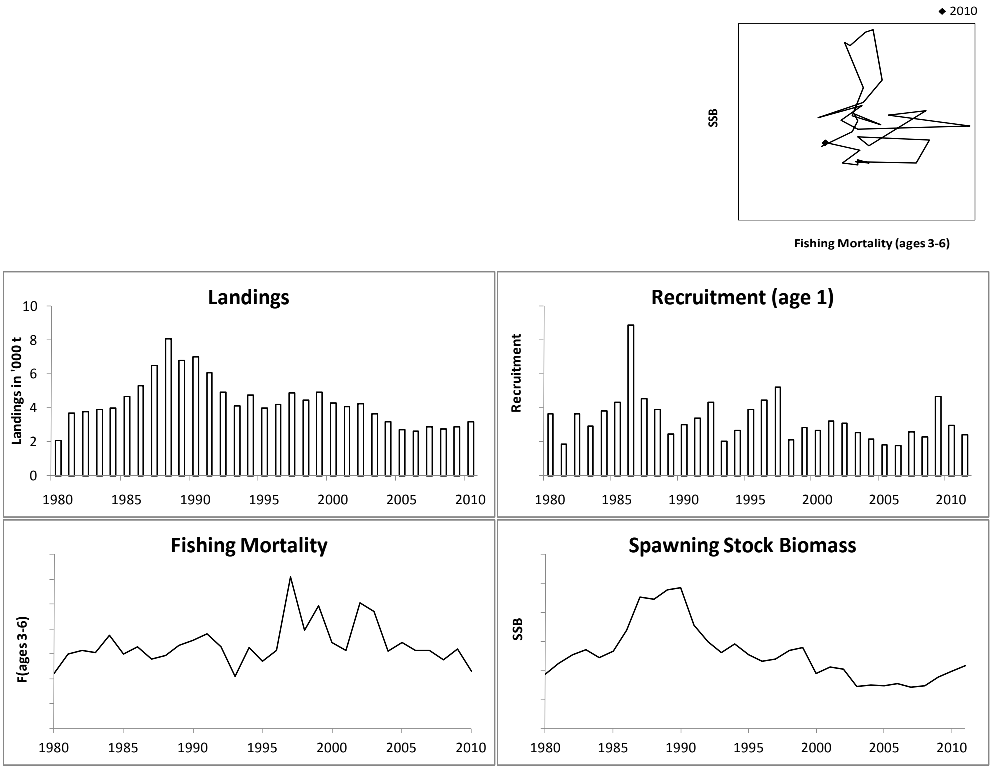

Figure 2.5.3.1. Plaice in Division VIId (Eastern Channel). Summary of stock trends (weights in '000 tonnes, Y-axis starts at 0). Top right: SSB and F over the years.

2.5.4 Category 4 – stocks for which survey-based assessments indicate trends

This category includes stocks for which survey indices are available that provide reliable indications of trends in total mortality, recruitment and biomass; e.g. Irish Sea haddock.

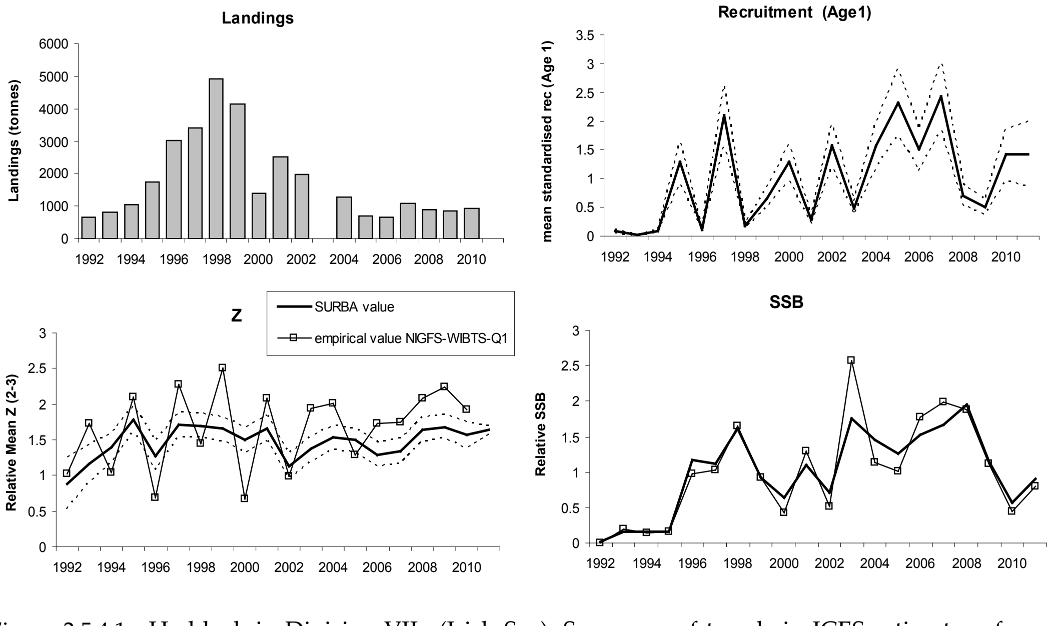

Figure 2.5.4.1. Haddock in Division VIIa (Irish Sea). Summary of trends in ICES estimates of landings (in tonnes, 2003 sampling was inadequate to derive catch age compositions), recruitment, total mortality (Z, empirical total mortality values from one survey are also shown for illustrative purposes), and spawning-stock biomass. Dotted lines are ±1 standard error.

2.5.5 Category 5 – stocks for which reliable catch data are available for short time-series

This category includes stocks for which catch curve analyses can be undertaken and an estimate of exploitation provided; e.g. plaice VIIh-k

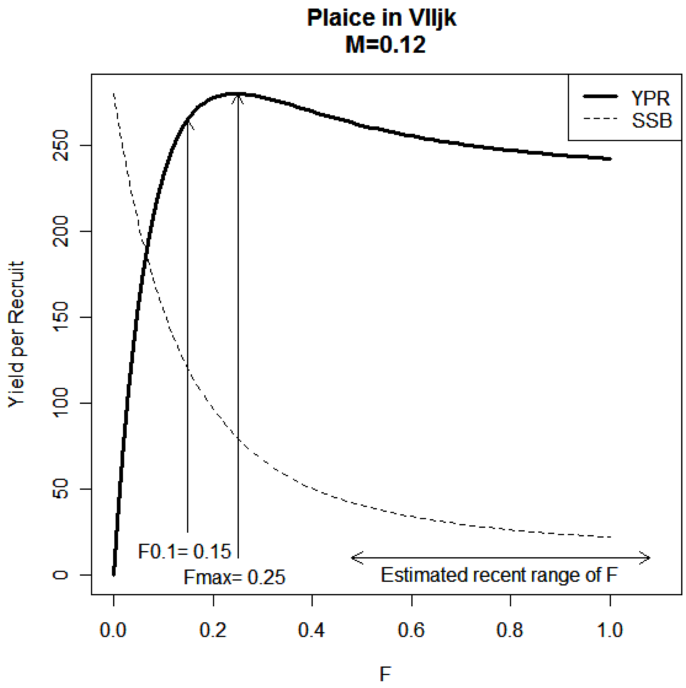

Figure 2.5.5.1. Plaice in Divisions VIIh–k. Yield per recruit plot and the range of recent fishing mortality estimates.

2.5.6 Category 6 – data-limited stocks

This category includes stocks for which only landings data are available; e.g. pollack in subareas VI and VII.

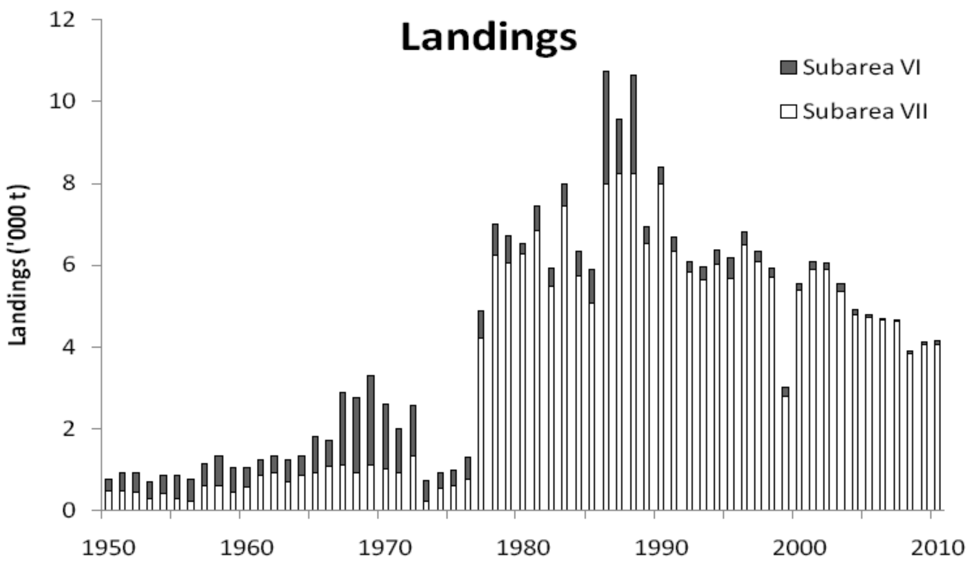

Figure 2.5.6.1. Pollack in Subareas VI and VII. Total official landings (tonnes) per country (2010 data is preliminary.

2.5.7 Category 7 - stocks caught in minor amounts as by-catch

This category includes stocks that are part of stock complexes and are primarily caught as by-catch species in other targeted fisheries; e.g. North Sea brill in the targeted North Sea plaice and sole fishery. The development of indicators may be most appropriate for such stocks.

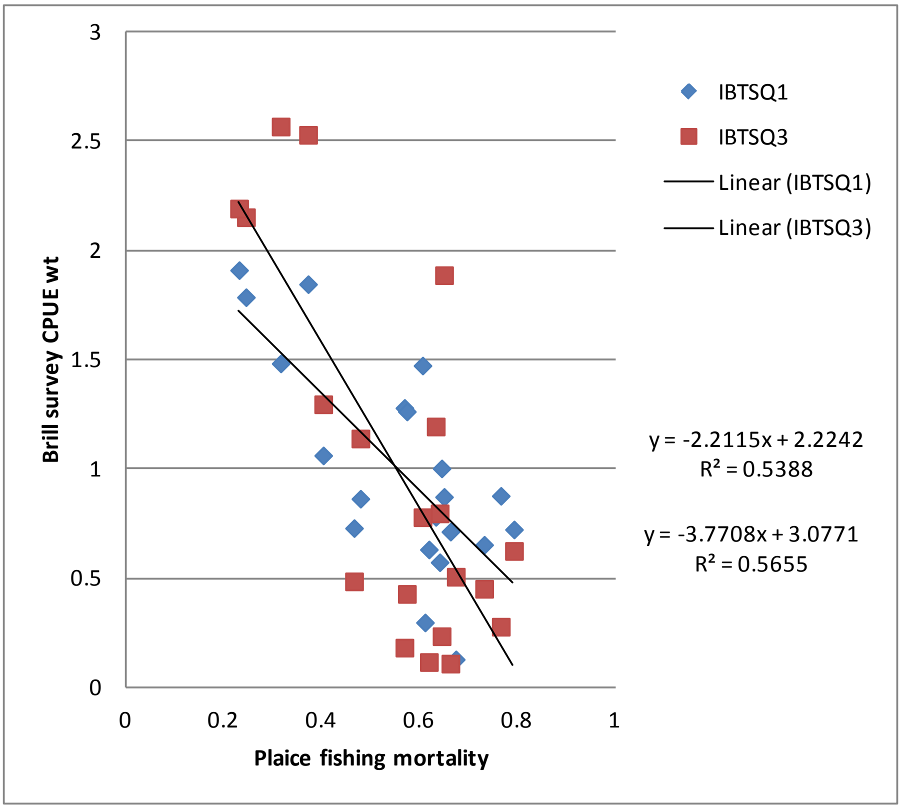

Figure 2.5.7.1. North Sea brill survey estimates of catch-per-unit-effort versus North Sea plaice estimates of fishing mortality.

2.6 Specific categorization of stocks by WKLIFE

The stocks considered by WKLIFE were classified according to the categories presented in Section 2.5, mainly based on looking at the ICES' advice summary sheets released last year in 2011. Stock categorization was performed for the majority of the stocks (103 in total) considered by WKLIFE (121 stocks in total). Two stocks have been recently benchmarked (WKRED 2012), have an accepted assessment methodology and were thus classified as category 1 (data-rich stocks – quantitative assessments). Only two stocks were classified as category 2 (negligible landings stocks). The majority of the stocks (59 stocks) were classified as categories 3 to 5 (stocks with analytical assessments and forecasts that are only treated qualitatively; stocks for which survey-based assessments indicate trends and stocks for which catch data are available for short time series) and many stocks (39 stocks) as categories 6 or 7 (stocks for which only landings data are available and stocks caught in minor amounts as by-catch). A brief description of the categorization by three sub-groupings I, II and III follows:

I – WGDEEP, WGEF and WGNEW stocks

II – WGNSSK, WGCSE, WGHMM and SECR stocks

III – NWWG, AFWG, WGPAND, HAWG, WGWIDE, WGHANSA, WGBFAS, WGBAST and WGEEL stocks

2.6.1 WGDEEP, WGEF and WGNEW stocks

Table 2.6.1.1 presents the categorization by stock and the rationale behind the classification. From the 44 stocks from WGDEEP, WGEF and WGNEW, 33 were classified: 23 stocks of categories 3 to 5 and only 9 stocks of categories 6 or 7.

Table 2.6.1.1 Categorization of WGDEEP, WGEF and WGNEW stocks addressed by WKLIFE.

Code	Stock name	EG	Category	Comment
lin-comb	Ling (*Molva molva*) in the Northeast Atlantic (I and II)	wgdeep		
lin-comb	Ling (*Molva molva*) in the Northeast Atlantic (Other areas except Va)	wgdeep		
lin-comb	Ling (*Molva molva*) in the Northeast Atlantic	wgdeep		
lin-comb	Ling (*Molva molva*) in the Northeast Atlantic	wgdeep		
bli-comb	Blue ling (*Molva dypterygia*) in the Northeast Atlantic (Vb, VI, VII and XIIb)	wgdeep	3	
bli-comb	Blue ling (*Molva dypterygia*) in the Northeast Atlantic	wgdeep		
bli-comb	Blue ling (*Molva dypterygia*) in the Northeast Atlantic	wgdeep		
usk-arct	Tusk in Subareas I and II (Arctic)	wgdeep	5	Reliable catch data, CPUE, no survey, no age readings, bycatch in mixed fishery
usk-mar	Tusk in Division XIIb (Mid Atlantic Ridge)	wgdeep	6	Several years without catches, no CPUE, no survey, bycatch in mixed fishery
usk-rock	Tusk in Division Vb (Rockall)	wgdeep	5	Reliable catch data, CPUE, no survey, no age readings, bycatch in mixed fishery
usk-oth	Tusk in Divisions IIIa, Iva, Vb, VI, VII, VIII, IX and XIIa (other areas)	wgdeep	5	Reliable catch data, CPUE, no survey, no age readings, bycatch in mixed fishery
arg-comb	Greater Silver Smelt (*Argentina Silus*) in the Northeast Atlantic (Va)	wgdeep	3	Reliable catch data from 1996. Survey indices from 2000
arg-comb	Greater Silver Smelt (*Argentina Silus*) in the Northeast Atlantic (all other areas)	wgdeep	4 or 5	Catch data from 1988. Survey indices from 2009
ory-comb	Orange Roughy (*Hoplostethus atlanticus*) in the Northeast Atlantic	wgdeep	6-7	
rng-comb	Roundnose grenadier (*Coryphaenoides rupestris*) in the Northeast Atlantic (Divisions Vb and XIIb	wgdeep	3	

	Subareas VI and VII)			
rng-comb	Roundnose grenadier (*Coryphaenoides rupestris*) in the Northeast Atlantic	wgdeep		
rng-comb	Roundnose grenadier (*Coryphaenoides rupestris*) in the Northeast Atlantic	wgdeep		
rng-comb	Roundnose grenadier (*Coryphaenoides rupestris*) in the Northeast Atlantic	wgdeep		
bsf-comb	Black scabbard fish (*Aphanopus carbo*) in the Northeast Atlantic (Vb VI, VII)	wgdeep	3	
bsf-comb	Black scabbard fish (*Aphanopus carbo*) in the Northeast Atlantic (IXa)	wgdeep	3	
bsf-comb	Black scabbard fish (*Aphanopus carbo*) in the Northeast Atlantic (other areas)	wgdeep	6	
gfb-comb	Greater forkbeard (*Phycis blennoides*) in the Northeast Atlantic	wgdeep		
alf-comb	Alfonsinos (*Beryx spp.*) in the Northeast Atlantic	wgdeep		
sbr-comb	Red (=blackspot) seabream (*Pagellus bogaraveo*) in the Northeast AtlanticVI, VI and VIII	wgdeep	4 or 5	collapsed, potential for survey based.
sbr-comb	Red (=blackspot) seabream (*Pagellus bogaraveo*) in the Northeast Atlantic (IXa = Strait of Gibraltar)	wgdeep	5	Time series 20 years
sbr-comb	Red (=blackspot) seabream (*Pagellus bogaraveo*) in the Northeast Atlantic (X Azores)	wgdeep	4 and 5	
skx-67-d	Demersal elasmobranchs in the Celtic Sea and West of Scotland	wgef	7	
skx-347d	Demersal elasmobranchs in the North Sea, Skagerrak and eastern English Channel	wgef	4	
skx-89a	Demersal elasmobranchs in the Bay of Biscay and Atlantic Iberian waters	wgef	4-7	
cyo-nea	Portuguese dogfish (*Centroscymnus coelolepis*) and leafscale gulper shark (*Centrophorus squamosus*) in the Northeast Atlantic (Vb, VI, VII)	wgef	7	
sck-nea	Kitefin shark (*Dalatias licha*) in the Northeast Atlantic (mainly X, Azores)	wgef	7	exist historical assessments based on Bayesian stock production model

dgs-nea	Spurdog (*Squalus acanthias*) in the Northeast Atlantic	wgef	3	
por-nea	Porbeagle (*Lamna nasus*) in the Northeast Atlantic	wgef	7	exist historical assessments based on Bayesian stock production model
bsk-nea	Basking shark (*Cetorhinus maximus*) in the Northeast Atlantic	wgef	7	
tur-nsea	Turbot in Subarea IV and Division IIIa	wgnew	3,5	long time series of catch and biodata
bll-nsea	Brill in Subarea IV and Divisions IIIa and VIId,e	wgnew	3,5	long time series of catch and biodata
dab-nsea	Dab in Subarea IV and Division IIIa	wgnew	3,5	long time series of catch and biodata
fle-nsea	Flounder in Division IIIa and Subarea IV	wgnew	3,5	long time series of catch and biodata
lem-nsea	Lemon sole in Subarea IV and Divisions IIIa and VIId	wgnew	3,5	Bycatch, TAC (combined with witch) not generally caught with witch, but statistics are separated, several survey indices, potential for stoock complex with plaice, YPR based on DCF data, to look at exploitation pattern
wit-nsea	Witch in Subarea IV, Division IIIa and VIId	wgnew	3,5	long time series of catch and biodata
bss-comb	European seabass in the Northeast Atlantic	wgnew	5	short times series
gur-comb	Red gurnard in the Northeast Atlantic	wgnew	5	short times series
gug-comb	Grey gurnard in the Northeast Atlantic	wgnew	5	Widely discarded, landings data not representative of catch. Some survey time series available for N.Sea
mut-comb	Striped red mullet in the Northeast Atlantic	wgnew	5	short times series

2.6.2 WGNSSK, WGCSE, WGHMM and SECR stocks

When the information base was categorised according to the 7 categories (see Section 2.5), (where categories 6 & 7 refer to stocks where there is landings data only or where the data represent a by-catch species in a mixed species fishery), 24 of the stocks were classified as category 6 or 7 (Table 2.6.2.1). Of these all have a time-series of at least landings, and in some cases there is data on landings and discards, and in some cases there are also indices, but these have not been used in any attempt at an assessment (for various reasons). This evaluation is based on looking at the advice summary sheets, but in many cases there may be more information in the ICES' Expert Groups (EGs), and it is likely that if an evaluation of the categories were redone by the relevant experts, that many of those stocks classified as category 6 could be moved to categories 5 or less. In any event the category 6 stocks which would need some kind of analyses applied based on catch (landings) data only. Methods which can be applied to catch data only are described in Section 2.2. There are 4 of these stocks which could be considered as category 7, implying that the exploitation may be primarily driven by (and linked to) fisheries on other stocks. In these cases there may be scope to provide an advice which is linked to the primary exploited stocks.

Table 2.6.2.1 Categorization of WGNSSK, WGCSE, WGHMM and SECR stocks addressed by WKLIFE.

Code	Stock name	EG	Category	Comment
nep-5	Nephrops in Division IVbc (Botney Gut - Silver Pit, FU 5)	wgnssk	6	Trends based on lpue information and mean sizes in the catches
nep-10	Nephrops in Division IVa (Noup, FU 10)	wgnssk	6	No assessment – only landings data and landings length frequencies. Occasional surveys
nep-32	Nephrops in Division IVa (Norwegian Deeps, FU 32)	wgnssk	6	Trends based on (Danish) lpue information and mean sizes in the catches
nep-33	Nephrops in Division IVb (Off Horn Reef, FU 33)	wgnssk	6	Trends based on lpue information and mean sizes in the catches
san-ns4	Sandeel in the Central Western North Sea (SA 4)	wgnssk	4	Landings and trawl survey data are available.
san-ns5	Sandeel in the Viking and Bergen Bank area (SA 5)	wgnssk	6	Landings statistics and acoustic data are available.
san-ns6	Sandeel in Division IIIa East (Kattegat, SA6)	wgnssk	6	Landing statistics and trawl survey data are available.
san-ns7	Sandeel in the Shetland area (SA 7)	wgnssk	6	Landings statistics and trawl survey data are available.
pol-nsea	Pollack in Subarea IV and Division IIIa	wgnssk	6	Landings only
whg-kask	Whiting in Division IIIa (Skagerrak - Kattegat) LOWER RANGE	wgnssk	6	Landings only
whg-kask	Whiting in Division IIIa (Skagerrak - Kattegat) UPPER RANGE	wgnssk	6	Landings only
ple-kask	Plaice in Division IIIa (Skagerrak - Kattegat) LOWER RANGE	wgnssk	6	Surveys available
ple-kask	Plaice in Division IIIa (Skagerrak - Kattegat) UPPER RANGE	wgnssk	6	Surveys available
ple-eche	Plaice in Division VIId (Eastern Channel)	wgnssk	3	Assessment model
ple-eche	Plaice in Division VIId (Eastern Channel)	wgnssk	3	Assessment model
ple-7h-k	Plaice in Divisions VIIh-k (Southwest of Ireland)	wgcse	5	Catch curve estimates of Z and YPR proxies for F_{MSY} available
ple-7b-c	Plaice in Division VIIb,c (West of Ireland)	wgcse	6	Only landings data and 2 divergent LPUE series
cod-rock	Cod in Division VIb (Rockall)	wgcse	4	Two LPUE series available with some consistency
whg-scow	Whiting in Division VIa (West of Scotland)	wgcse	4	Landings, discards and survey index available
whg-rock	Whiting in Division VIb (Rockall)	wgcse	6	Some landings in the 1990s, but very low before and after
ang-ivvi	Anglerfish (*Lophius piscatorius* and *L. budegassa*) in Divisions IIa, IIIa, Subarea IV and VI	wgcse	4	Landings and survey trends available

ang-ivvi	Anglerfish (*Lophius piscatorius* and *L. budegassa*) in Divisions IIa, IIIa, Subarea IV and VI	wgcse	4	Landings and survey trends available
had-iris	Haddock in Division VIIa (Irish Sea)	wgcse	4	unreliable catch data due to discard sampling problems but age based TSA using survey index
nep-16	Nephrops in Division VIIb,c,j,k (Porcupine Bank, FU 16)	wgcse	6	Trends based on cpue and lpue and size composition in the catches and landings
nep-19	Nephrops in Division VIIa,g,j (South East and West of IRL, FU 19)	wgcse	4	Survey trends. Landings, effort and lpue available.
nep-2022	Nephrops in Division VIIf,g,h (Celtic Sea, FU 20-22)	wgcse	4	UWTV and trends, catch options based on UWTV for FU 22
sol-7h-k	Sole in Divisions VIIh-k (Southwest of Ireland)	wgcse	5	Catch curve estimates of Z and YPR proxies for F_{MSY} available
sol-7b-c	Sole in Division VIIb, c (West of Ireland)	wgcse	6	Only landings data and 2 divergent LPUE series
meg-4a6a	Megrim (*Lepidorhombus spp*) in Divisions IVa and VIa	wgcse	3	No CAA data but production model applied to catch & survey data
meg-rock	Megrim (*Lepidorhombus spp*) in ICES Division VIb (Rockall)	wgcse	6	Landings & CPUE index
had-7b-k	Haddock in Divisions VIIb-k	wgcse	3	Trends XSA assessment
pol-celt	Pollack in Subareas VI and VII (Celtic Sea and West of Scotland)	wgcse	6	Landings only, could be more than one management unit
whg-iris	Whiting in Division VIIa (Irish Sea) LOWER RANGE	wgcse	2	Discard fishery
whg-iris	Whiting in Division VIIa (Irish Sea) UPPER RANGE	wgcse	2	Discard fishery
whg-7e-k	Whiting in Division VIIe-k LOWER RANGE	wgcse	4	Survey trends
whg-7e-k	Whiting in Division VIIe-k UPPER RANGE	wgcse	4	Survey trends
ple-iris	Plaice in Division VIIa (Irish Sea) LOWER RANGE	wgcse	3	Assessment model
ple-iris	Plaice in Division VIIa (Irish Sea) UPPER RANGE	wgcse	3	Assessment model
ple-celt	Plaice in Divisions VIIf,g (Celtic Sea)	wgcse	3	Assessment model
mgw-78	Megrim (*Lepidorhombus whiffiagonis*) in Divisions VIIb-k and VIIIa,b,d	wghmm	4	CPUE and survey indices available. Assessment based on survey trends
ang-78ab	Anglerfish (*Lophius piscatorius* and *L. budegassa*) in Divisions VIIb-k and VIIIa,b,d LOWER RANGE	wghmm	4	Survey trends well
ang-78ab	Anglerfish (*Lophius piscatorius* and *L. budegassa*) in Divisions VIIb-k and VIIIa,b,d UPPER RANGE	wghmm	4	Survey trends well

nep-25	Nephrops in North Galicia (FU 25)	wghmm	6	Trends based on lpue information and mean sizes in the catches
nep-31	Nephrops in the Cantabrian Sea (FU 31)	wghmm	6	Trends based on lpue information and mean sizes in the catches
nep-2627	Nephrops in West Galicia and North Portugal (FU 26-27)	wghmm	6	Trends based on lpue information and mean sizes in the catches
nep-2829	Nephrops in South-West and South Portugal (FU 28-29)	wghmm	3	Full assessment accepted for trends. Interbenchmark going on
nep-30	Nephrops in Gulf of Cadiz (FU 30)	wghmm	6	Trends based on lpue information and mean sizes in the catches
sol-8c9a	Sole in Divisions VIIIc and IXa	wghmm	7	By-catch species. Landings data presented in 2011 for the first time
ple-89a	Plaice in Subarea VIII and Division IXa	wghmm	7	By-catch species. Landings data presented in 2011 for the first time
pol-89a	Pollack in Subarea VIII and Division IXa	wghmm	7	By-catch species. Landings data presented in 2011 for the first time
whg-89a	Whiting in Subarea VIII and Division IXa	wghmm	7	By-catch species. Landings data presented in 2011 for the first time
nop-scow	Norway pout in Division VIa	secr		
san-scow	Sandeel in Division VIa	secr		

2.6.3 NWWG, AFWG, WGPAND, HAWG, WGWIDE, WGHANSA, WGBFAS, WGBAST and WGEEL stocks

Firstly, ICES does not have an accepted time-series of stock wide catch for eel and consequently, eel will not be considered further by WKLIFE as previously remarked upon in Section 1.1. No further reference will be made to eel and it will be excluded from the analyses and discussions presented later in Section 5.

Of the remaining stocks covered by the WG grouping in this Section 2.6.3, two stocks were classified as category 1 (data rich stocks): the Beaked Redfish (*Sebastes mentella*) and the Golden Redfish (*Sebastes mentella*) in Subareas I and II (Table 2.6.3.1). These stocks have been benchmarked recently (WKRED 2012) and an assessment has been adopted and approved. Blue jack mackerel (*Trachurus picturarus*) in Subdivision Xa2 (Azores) was tentatively classified as category 1 but relevant experts on this stock were not present at the workshop. Several stocks were classified as categories 3 to 5 which could preclude assessments based on survey data and/or catch curve analysis as a basis for advice (see Section 6.1).

Table 2.6.3.1 Categorization of NWWG, AFWG, WGPAND, HAWG, WGWIDE, WGHANSA, WGBFAS and WGBAST stocks addressed by WKLIFE.

Code	Stock name	EG	Category	Comment
cod-ewgr	Cod in ICES Subarea XIV and NAFO Subarea 1 (Greenland cod)	nwwg	4,[5]	Offshore stock, survey trends only used in advice, but catch statistisc are available
	Cod in NAFO subarea 1 inshore		5	new stock (request of dividing advise in inshore and offshore stock), survey data on recruitment available
	Greenland halibut in NAFO subarea 1A inshore		[4],5	3 different inshore NAFO assessed stocks based on catch statistisc, but survey data are available
smn-dp	Beaked Redfish (*Sebastes mentella*) in Subareas V, XII, XIV and NAFO Subareas 1+2 (Deep Pelagic stock > 500 m deep)	nwwg	4,6	reliable catch statistics; survey index scattered in time and considered a poor biomass indicator
smn-grl	Beaked Redfish (*Sebastes mentella*) in Subarea XIVb (Demersal)	nwwg	4,6	dubius catch statistics due to species mixing; survey index available but short time series
smr-5614	Golden Redfish (*Sebastes marinus*) in Subareas V, VI, XII and XIV	nwwg	[1],4	WKRED 2012 adopted gadget model, survey index considered good biomass indicator
smn-con	Beaked Redfish (*Sebastes mentella*) in Division Va and Subarea XIV (Icelandic Slope stock)	nwwg	4,6	catch statistics and survey
smn-sp	Beaked Redfish (*Sebastes mentella*) in Subareas V, XII, XIV and NAFO Subareas 1+2 (Shallow Pelagic stock < 500 m deep)	nwwg	4,6	catch statistics and acoustic survey - considered reliable but scattered in time and relatively short time series
cod-farb	Cod in Subdivision Vb2 (Faroe Bank)	nwwg	4	length information available
cod-coas	Cod in Subareas I and II (Norwegian coastal cod)	afwg	3	
smn-arct	Beaked Redfish (*Sebastes mentella*) in Subareas I and II	afwg	1	WKRED adopted gadget model
smr-arct	Golden Redfish (*Sebastes marinus*) in Subareas I and II	afwg	1	WKRED adopted gadget model
ghl-arct	Greenland halibut in Subareas I and II	afwg	4,6	catch statistics and survey; awaiting validation of age reading
pan-barn	Northern shrimp (*Pandalus borealis*) in Subareas I and II (Barents Sea)	wgpand		
pan-flad	Northern shrimp (*Pandalus borealis*) in Division IVa (Fladen Ground)	wgpand	6	
pan-sknd	Northern shrimp (*Pandalus borealis*) in Divisions IIIa West and IVa East (Skagerrak and Norwegian Deeps)	wgpand	4, [5]	stage based model could be applied

her-nirs	Herring in Division VIIa North of 52° 30' N (Irish Sea)	hawg	[1],3	
her-irlw	Herring in Divisions VIa (South) and VIIb,c	hawg	3,4	
spr-ech	Sprat in Divisions VIId,e	hawg	6	a stock?
spr-celt	Sprat in the Celtic Sea and West of Scotland	hawg	6	a stock?
spr-kask	Sprat in Division IIIa (Skagerrak - Kattegat)	hawg	6	
spr-nsea	Sprat in Subarea IV (North Sea)	hawg	[4],6	
hom-nsea	Horse mackerel (*Trachurus trachurus*) in Divisions IIIa, IVb,c and VIId (North Sea stock)	wgwide	[1,3],6	
boc-nea	Boarfish in the Northeast Atlantic	wgwide		
jaa-10	Blue jack mackerel (*Trachurus picturatus*) in Subdivision Xa2 (Azores)	wghansa	[1]	new MoU stock
ane-pore	Anchovy in Division IXa	wghansa	3	
ple-2232	Plaice in Subdivisions 22 - 32 (Baltic Sea)	wgbfas	4.5	length based model could be applied
dab-2232	Dab in Subdivisions 22 - 32 (Baltic Sea)	wgbfas	4.5	length based model could be applied
tur-2232	Turbot in Subdivisions 22 - 32 (Baltic Sea)	wgbfas	4.5	length based model could be applied
bll-2232	Brill in Subdivisions 22 - 32 (Baltic Sea)	wgbfas	4.5	length based model could be applied
her-31	Herring in Subdivision 31 (Bothnian Bay)	wgbfas	3?	
fle-2232	Flounder in Subdivisions 22 - 32 (Baltic Sea)	wgbfas	4.5	length based model could be applied
sal-32	Salmon in Subdivision 32 (Gulf of Finland)	wgbast		
trt-bal	Sea Trout in Subdivisions 22 - 32 (Baltic Sea)	wgbast		

2.7 Preliminary evaluation of the WKFRAME3 catch rule

The work presented in WD2 uses the Management Strategy Evaluation (MSE) framework to evaluate the catch rule proposed by WKFRAME3 in terms of its ability to meet MSY objectives. The catch rule relies on the availability of a time-series of a survey biomass index, and combines three factors in order to provide total allowable catch (TAC) advice; namely, a survey biomass trend factor, a precautionary scale-down factor relating current biomass to a trigger level, and a factor relating current exploitation to MSY levels. The catch rule is intended to be used in circumstances where no analytical assessment exists, so scaling to true stock size becomes a problem, and the rule relies on proxies for current stock size and MSY levels. Although the preliminary study in WD2 does not help with the problems associated with estimating the three factors, in particular with scaling the biomass index and using suitable proxies, they do however explore the behaviour of the catch rule, both when the scaling and proxies are appropriate, and when they are not, and under scenarios representing a limited range of uncertainties.

The main conclusions are: unbiased estimates of MSY/B_{MSY} (the MSY rate), exploitation rate and survey catchability are needed in order to deliver MSY targets; where a time-lag in the factor relating current exploitation to MSY levels is unavoidable, a TAC constraint is needed to stabilise the catch rule and a substantially higher risk of unintended stock depletion to low levels is evident; when applying the precautionary scale-down factor, it is better to set the biomass trigger level too high than too low.

3 Sub-group I: WGDEEP, WGEF and WGNEW stocks

3.1 Proxies for F_{MSY} based on life-history traits (ToR a and d)

The complete list of stocks is given in Table 3.1.1 together with an indication of L_{max} and L_{inf}. Note that in the Table 3.1.1 as L_{max} corresponds to the largest fish measured it can exceptionally be longer than the L_{inf} which is the theoretical maximum length based on all the length-at-age data.

Table 3.1.1 Life history parameters.

Code	Stock name	EG	Lmax (cm)	Linf (cm)
lin-comb	Ling (Molva molva) in the Northeast Atlantic (I and II)	wgdeep	200	150
lin-comb	Ling (Molva molva) in the Northeast Atlantic (Other areas except Va)	wgdeep	200	119
lin-comb	Ling (Molva molva) in the Northeast Atlantic	wgdeep		
lin-comb	Ling (Molva molva) in the Northeast Atlantic	wgdeep		
bli-comb	Blue ling (Molva dypterygia) in the Northeast Atlantic (Vb, VI, VII and XIIb)	wgdeep	148	140
bli-comb	Blue ling (Molva dypterygia) in the Northeast Atlantic	wgdeep		
bli-comb	Blue ling (Molva dypterygia) in the Northeast Atlantic	wgdeep		
usk-arct	Tusk in Subareas I and II (Arctic)	wgdeep		
usk-mar	Tusk in Division XIIb (Mid Atlantic Ridge)	wgdeep		
usk-rock	Tusk in Division Vb (Rockall)	wgdeep		
usk-oth	Tusk in Divisions IIIa, Iva, Vb, VI, VII, VIII, IX and XIIa (other areas)	wgdeep		
arg-comb	Greater Silver Smelt (Argentina Silus) in the Northeast Atlantic (Va)	wgdeep		
arg-comb	Greater Silver Smelt (Argentina Silus) in the Northeast Atlantic (all other areas)	wgdeep		
ory-comb	Orange Roughy (Hoplostethus atlanticus) in the Northeast Atlantic	wgdeep		
rng-comb	Roundnose grenadier (Coryphaenoides rupestris) in the Northeast Atlantic (Divisions Vb and XIIb Subareas VI and VII)	wgdeep	25	28.7
rng-comb	Roundnose grenadier (Coryphaenoides rupestris) in the Northeast Atlantic	wgdeep		

rng-comb	Roundnose grenadier (Coryphaenoides rupestris) in the Northeast Atlantic	wgdeep		
rng-comb	Roundnose grenadier (Coryphaenoides rupestris) in the Northeast Atlantic	wgdeep		
bsf-comb	Black scabbard fish (Aphanopus carbo) in the Northeast Atlantic (Vb VI, VII)	wgdeep		
bsf-comb	Black scabbard fish (Aphanopus carbo) in the Northeast Atlantic (IXa)	wgdeep		
bsf-comb	Black scabbard fish (Aphanopus carbo) in the Northeast Atlantic (other areas)	wgdeep		
gfb-comb	Greater forkbeard (Phycis blennoides) in the Northeast Atlantic	wgdeep		
alf-comb	Alfonsinos (Beryx spp.) in the Northeast Atlantic	wgdeep		
sbr-comb	Red (=blackspot) seabream (Pagellus bogaraveo) in the Northeast AtlanticVI, VI and VIII	wgdeep	70	51.4
sbr-comb	Red (=blackspot) seabream (Pagellus bogaraveo) in the Northeast Atlantic (IXa = Strait of Gibraltar)	wgdeep		
sbr-comb	Red (=blackspot) seabream (Pagellus bogaraveo) in the Northeast Atlantic (X Azores)	wgdeep		
skx-67-d	Demersal elasmobranchs in the Celtic Sea and West of Scotland	wgef	55	42.4
skx-347d	Demersal elasmobranchs in the North Sea, Skagerrak and eastern English Channel	wgef		
skx-89a	Demersal elasmobranchs in the Bay of Biscay and Atlantic Iberian waters	wgef		
cyo-nea	Portuguese dogfish (Centroscymnus coelolepis) and leafscale gulper shark (Centrophorus squamosus) in the Northeast Atlantic (Vb, VI, VII)	wgef		
sck-nea	Kitefin shark (Dalatias licha) in the Northeast Atlantic (mainly X, Azores)	wgef	182	
dgs-nea	Spurdog (Squalus acanthias) in the Northeast Atlantic	wgef	160	
por-nea	Porbeagle (Lamna nasus) in the Northeast Atlantic	wgef	350	
bsk-nea	Basking shark (Cetorhinus maximus) in the Northeast Atlantic	wgef	900	
tur-nsea	Turbot in Subarea IV and Division IIIa	wgnew	100	61.2
bll-nsea	Brill in Subarea IV and Divisions IIIa and VIId,e	wgnew		
dab-nsea	Dab in Subarea IV and Division IIIa	wgnew	40	36
fle-nsea	Flounder in Division IIIa and Subarea IV	wgnew	42.7	36.2
lem-nsea	Lemon sole in Subarea IV and Divisions IIIa and VIId	wgnew	51	40
wit-nsea	Witch in Subarea IV, Division IIIa and VIId	wgnew	60	47
bss-comb	European seabass in the Northeast Atlantic	wgnew		
czs-comb	Spiny red gurnard in the Northeast Atlantic	wgnew		
gug-comb	Grey gurnard in the Northeast Atlantic	wgnew	60	46
mut-comb	Striped red mullet in the Northeast Atlantic	wgnew	40	53.3

Deep-water species are mainly k-strategists. However, they may present quite different population dynamics, which are considered to reflect different adaptions to the deep-sea. Under this rational the following species were selected

Roundnose grenadier - long lived (~60 years old) and slow moving species widely distributed in the North Atlantic; with no evidence of long distance migrations made by adult fish.

Blue ling – species known to form spawning aggregations; with a life cycle similar to other gadoid species but with a higher longevity.

Red seabream – bentho-pelagic species inhabiting various types of bottom down to a depth of 900 m; protandric hermaphrodite; the species changes from males to females at age 8.

Black scabbardfish – this species is widely distributed; the life cycle is not completed in just one area, may present either small or large-scale migrations seasonally.

The selected species from the WGNEW were lemon sole and red gurnard**.** These two species are by-catches species in demersal trawl fisheries. Both are of significant unit value. Red gurnard grow faster with an earlier age at first maturity so would be expected to trend towards r strategy when compared with lemon sole which would tend towards K strategy.

The estimates obtained for each of these species by the three different methods are summarized in Table 3.1.2 below. Note that AFC1 and AFC2 refer to *age 1 at first capture* and *age 2 at first capture*, respectively.

Table 3.1.2 Proxies for F reference points derived from four methods for six species with contrasted life-history traits. GISLASIM: life-history simulator under FLR (see section 2.3.1), MSY *Catch-MSY method* (Section 2.2.2) , AFC1 and AFC2.

		GISLASIM		MSY		AFC1		AFC2	
Blue ling (Molva dypterygia) in the Northeast Atlantic (Vb, VI, VII and XIIb)		f0.1	NA			Fmax'	0,15	Fmax'	0,18
M	0,18	fmax	NA			F0.1'	0,09	F0.1'	0,1
K	0,13	spr.30	NA			F30'	0,1	F30'	0,11
		msy	NA	f_MSY + 2 SD	0,17	F35'	0,09	F35'	0,1
		crash	NA	f_MSY	0,12	F40'	0,07	F40'	0,08
				f_MSY - 2 SD	0,09	F10'	0,23	F10'	0,27
Black scabbard fish (Aphanopus carbo) in the Northeast Atlantic (Vb VI, VII)		f0.1	0,14			Fmax'	0,14	Fmax'	0,17
M	0,2	fmax	0,42			F0.1'	0,09	F0.1'	0,1
K	0,17	spr.30	0,22			F30'	0,1	F30'	0,11
		msy	0,12	f_MSY + 2 SD	0,39	F35'	0,08	F35'	0,09
		crash	0,49	f_MSY	0,22	F40'	0,07	F40'	0,08
				f_MSY - 2 SD	0,12	F10'	0,22	F10'	0,26
Roundnose grenadier (Coryphaenoides rupestris) in the Northeast Atlantic (Divisions Vb and XIIb Subareas VI and VII)		f0.1	0,07			Fmax'	0,79	Fmax'	1,12
M	0,1	fmax	2,E+04			F0.1'	0,4	F0.1'	0,5
K	0,035	spr.30	0,04			F30'	0,41	F30'	0,75
		msy	0,03	f_MSY + 2 SD	-	F35'	0,35	F35'	0,61
		crash	0,06	f_MSY	-	F40'	0,3	F40'	0,5
				f_MSY - 2 SD	-	F10'	0,92	F10'	2
Red (=blackspot) seabream (Pagellus bogaraveo) in the Northeast AtlanticVI, VI and VIII		f0.1	0,15			Fmax'	0,42	Fmax'	0,6
M	0,2	fmax	0,49			F0.1'	0,23	F0.1'	0,28
K	0,169	spr.30	0,15			F30'	0,24	F30'	0,32
		msy	0,26	f_MSY + 2 SD	-	F35'	0,2	F35'	0,27
		crash	0,92	f_MSY	-	F40'	0,17	F40'	0,23
				f_MSY - 2 SD	-	F10'	0,54	F10'	0,81
red gurnard in the Northeast Atlantic		f0.1	0,63			Fmax'	0,54	Fmax'	0,65
M from tmax (Hoenig 1984)	0,26	fmax	1,6E+17			F0.1'	0,29	F0.1'	0,35
K from Jennings et al 1999	0,49	spr.30	0,72			F30'	0,29	F30'	0,24
		msy	1,69	f_MSY + 2 SD	-	F35'	0,25	F35'	0,2
		crash	5,47	f_MSY	-	F40'	0,21	F40'	0,18
				f_MSY - 2 SD	-	F10'	0,66	F10'	0,48
Lemon sole in Subarea IV and Divisions IIIa and VIId		f0.1	0,33			Fmax'	0,55	Fmax'	0,8
M from tmax (Hoenig 1984)	0,29	fmax	3,0E+16			F0.1'	0,29	F0.1'	0,36
K	0,3	spr.30	0,23			F30'	0,3	F30'	0,43
		msy	0,32	f_MSY + 2 SD	0,31	F35'	0,25	F35'	0,36
		crash	0,79	f_MSY	0,23	F40'	0,22	F40'	0,3
				f_MSY - 2 SD	0,17	F10'	0,67	F10'	1,16

Reference points for stocks need to be determined using as much information as possible, and should include information on the exploitation pattern of the fisheries acting upon them. For cases where there is almost no information, inputs for the methods should rely on expert judgment using related species and fisheries. In these cases, care should be taken to ensure that realistic estimates be used. Sensitivity analysis should be carried out, examining the effects of the estimated variables on the outcome of the modeling process. As a guide for selecting the reference points, comparison could be made between estimates of F_{MSY} obtained by the methods and proxies derived from vital parameters, such as natural mortality and growth. For example the estimate of F_{MSY} for red gurnard by the Gislason method is probably too high, especially when compared with the relative growth rate of the species.

For the slowest growing species in the Table 3.1.1 roundnose grenadier, the F_{MSY} estimate is in accordance with the growth of the species, suggesting that the input parameters were consistent with the species dynamics and the exploitation pattern described for this stock.

3.2 Estimation of current exploitation (ToR b and c)

Reference points were calculated for some test species using the FLR gislasim() function described in Section 2.3 (source code and tutorial for running an example)

3.2.1 Example of use for Southern hake

The gislasim() function is used to pass the life history parameters and has the following arguments:

```
>library(FLAdvice)

>hk1p   <-   gislasim(FLPar(linf=130,   k=0.16,   t0=-0.1,   a=0.00659,
b=3.01721))

> plot (hk1p)
```

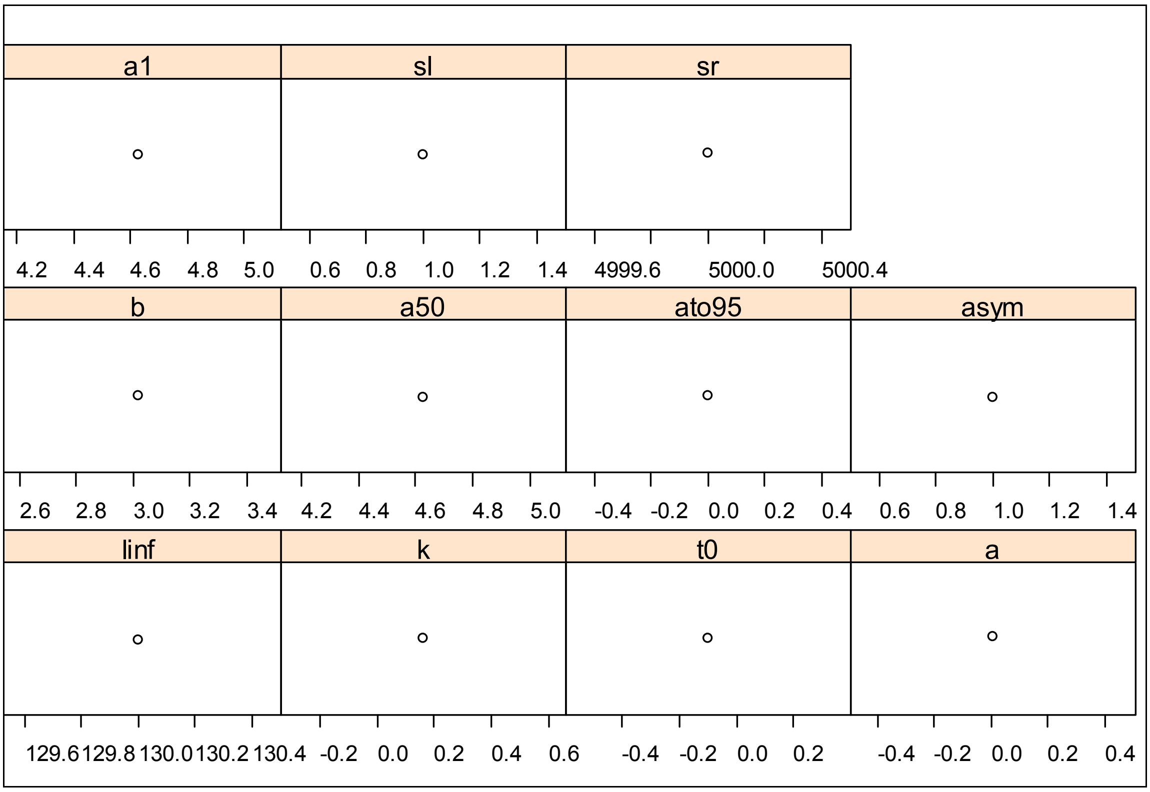

Figure 3.2.1.1. Plot of the life history parameters being used for simulating the Southern hake stock.

Use a Beverton Holt S/R reparametrized as a function of steepness and virgin biomass.

```
>hk1 <- lh(hk1p, age=(1:20), sr=list(model="bevholt",
steepness=0.95, vbiomass=1e3))
```

```
Selectivity Patterns need to be specified, we need to know something
about it.
```

```
>hk1p['a1',] <- 3 age full recruitment
>hk1p['sl',] <- 1 shape of the selectivity pattern
```

Once the simulated stock at equilibrium is built, Y/R reference points can be estimated using

```
>refpts(hk1)
```

```
An object of class "FLPar"
        quantity
refpt    harvest    yield      rec        ssb        biomass
  f0.1   1.6400e-01 5.7957e+01 3.5787e+03 3.3347e+02 6.7451e+02
  fmax   4.3889e-01 6.0404e+01 3.3079e+03 1.0656e+02 4.1065e+02
  spr.30 1.9145e-01 5.9876e+01 3.5585e+03 2.9051e+02 6.2836e+02
  msy    2.9937e-01 6.2342e+01 3.4652e+03 1.8005e+02 5.0433e+02
  crash  1.3952e+00 1.4370e-05 8.2507e-04 2.9558e-06 7.1620e-05
```

The Y/R plots are generated with the plot command

```
>plot(hk1)
```

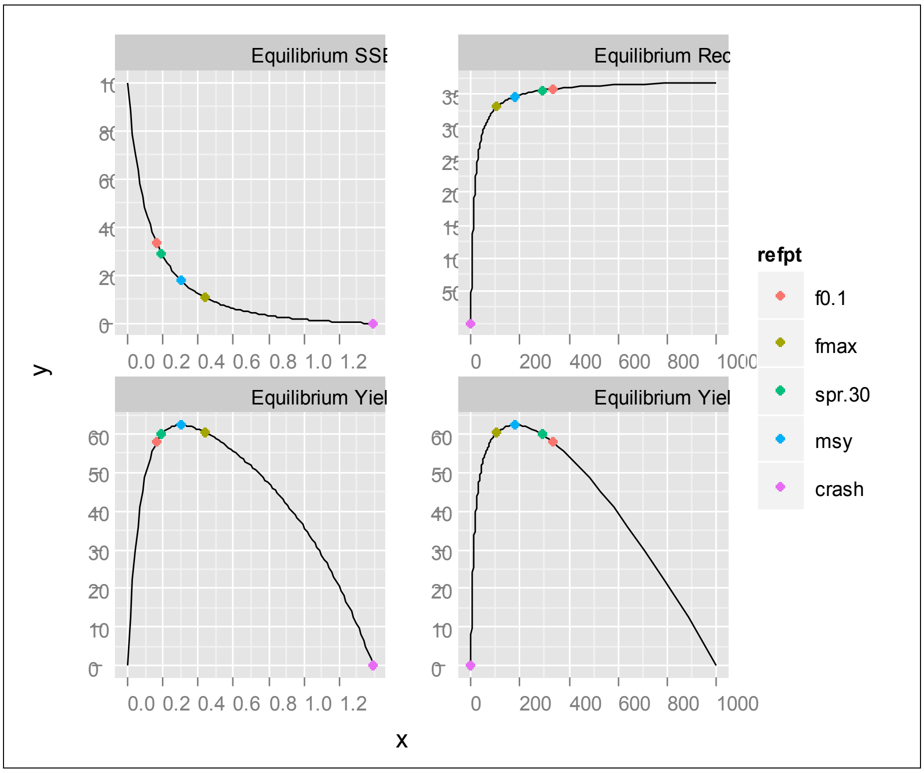

Figure 3.2.1.2. Reference points (F0.1, Fmsy, Fmax and SPR.30) for Southern Hake based on the gislasim() stock simulator

3.2.2 Deriving MSY reference points from DCAC

DCAC (available in the NOAA toolbox http://nft.nefsc.noaa.gov/DCAC.html), Depletion-corrected average catch, is a *"simple formula for estimating sustainable yields in data-poor situations"* as stated in the original article on this model (MacCall, 2009). The formula is an extension of the potential yield formula, and it provides useful estimates of sustainable yield for data-poor fisheries on long-lived species. Over an extended period, e.g. a decade or more, the catch is divided into a sustainable yield component and an unsustainable "windfall" component associated with a one-time reduction in stock biomass. The size of the windfall is expressed as being equivalent to a number of years of sustainable production, in the form of a "windfall ratio". The DCAC is calculated as the sum of catches divided by the sum of the number of years in the catch series and this windfall ratio.

The potential yield expression is:

$Ypot = 0.5B_0M$ where: M is the natural mortality

B_0 is the unexploited biomass

MacCall (2009) further refined it as:

$$Ypot = 0.4B_0cM$$

Where c is the ratio of F_{MSY} to M. At B_{MSY} level, *Ypot* is achieved with a fishing mortality of cM where c is usually <=1. The parameter c may be in the range 0.6-0.8 for vulnerable species (Walters and Martell, 2004). The ratio $0.5B_0$ is further replaced by $0.4B_0$ because $0.4B_0$ has been proposal as the biomass level where MSY is achieved (see MacCall, 2009).

Over a period of time, the windfall, i.e. the unsustainable part of the catch, corresponds to the stock biomass depletion:

$W = Bfyr - Blyr$

Where *Bfyr* and *Blyr* are the stock biomass in the first and last years. Note that if there was no change in the stock biomass during the period, *W=0,* the catch was sustainable. In situations where *Bfyr* and *Blyr* are known, there might be sufficient data for more elaboarte population models. The DCAC model applies in situations where the absolute biomass is not known but some knowledge, e.g. expert knowledge or a relative biomass index can provide a relative estimate of the ratio of biomass decline to the unexploited biomass: $\Delta = (Bfyr - Blyr)/B_0$.

The windfall ratio, i.e. number of years of sustainable yield corresponding to the one-time windfall can then be expressed as:

$$\frac{W}{Ypot} = \frac{Bflyr - Blyr}{0.4B_0cM} = \frac{\Delta B_0}{0.4B_0cM} = \frac{\Delta}{0.4cM}$$

where the rightmost term is released of the three "data-rich" quantities B_0, *Bfyr* and *Blyr* (MacCall, 2009).

Assuming that, on average, each year produces one unit of annual sustainable yield, the cumulated catch is the sum of two components, one derived from sustainable annual production, and the other from a one-time windfall harvest. The cumulative catch (ΣC) consists of *n* years of sustainable production, plus a windfall equivalent to *W/Ypot* years of potential yield. The DCAC provides an estimate of the yield that could have been sustained (*Ysust*) during that period:

$$Y_{sust} = \frac{\sum C}{n + \frac{W}{Ypot}} = \frac{\sum C}{n + \Delta / 0.4cM}$$

The input information to DCAC is:

- ΣC, the cumulated catches over the considered time-series,

- n, the number of years,

- Δ the relative reduction in biomass during the period,

- *M* the natural mortality, which should not exceed 0.2

- c the assumed ratio of F_{MSY} to *M*.

These input values are expected to be approximate, and based on the estimates of their imprecision, the uncertainty can be integrated by Monte Carlo exploration of DCAC values. In must however be kept in mind that the input values and, moreover, their variance are guess estimates in data-poor situation.

DCAC was run for three stocks: blue ling in Subareas VI and VII and Divisions Vb and XIIb, blackspot seabream in Subareas VI, VII and VIII and orange roughy in Subarea VI.

Blue ling in Subareas VI and VII and Divisions Vb and XIIb

Blue ling was classified category 3 because assessments are carried out both with production models and age structure models. Theses assessments have not been yet considered sufficiently reliable for use as basis for advice. Nevertheless, much more data than LHTs only area available. Commercial CPUE trends are estimated (Lorance et al., 2009), some limited survey indices are useful as abundance indices (ICES 2011a), simple catch curves have been used to estimate the total mortality *Z* (ICES 2011a) and a Multi-Year Catch Curve (MYCC) model is under development in the DEEPFISHMAN project.

Reference points for the stock are missing, DCAC was used to assess a possible level of MSY.

DCAC was already applied to blue ling harvested for 43 years, from 1966 to 2008 by WGDEEP 2010. A previous use of DCAC by WGDEEP 2010 with an M then fixed at 0.22 yr^{-1}, should not be considered because (1) DCAC is not appropriate for such a high *M* (MacCall, 2009) and (2) *M* is lower for blue ling. WGDEEP has been using *M*=0.15 for some trial assessments, the FP7 project DEEPFISHMAN uses the same values for XSA runs, Management Strategy Evaluation (MSE) and stock simulations and the MYCC model suggests *M*=0.18. The higher *M*=0.22 resulted of applying Hewitt and Hoening (2005) empirical relation with longevity, assumed to be 20 yr for blue ling. DCAC runs carried out in WKLIFE used a range of M from 0.15 to 0.18. *c* was set to 0.8.

Based upon result from the MYCC, DCAC was applied to years 1966-2004 as after 2004, the stock have increased. The first years of this time-series correspond to low exploitation levels until 1973.

A range of delta-depletion values were tried as a simple sensitivity analysis. Standard error values for the parameters *M*, F_{MSY}/M, B_{MSY}/B0 and Δ were obtained by assuming reasonable coefficients of variation, following recommendations by MacCall (2009). Standard deviations were set respectively to 0.5, 0,2, 0.1 and 0.1. The known parameter values (number of years of fishery and total catch in that period) were set at their values and the unknown parameters were collected from normal distributions in a Monte Carlo simulation experiment to obtain resampled 95% confidence intervals for MSY for each value of *Δ*. DCAC was run from the NOAA Fisheries Toolbox (http://nft.nefsc.noaa.gov/).

Table 3.2.2.1 DCAC output for blue ling

Depletion Delta	0.5	0.6	0.7	0.8
Years	1966-2004	1966-2004	1966-2004	1966-2004
Nb years	39	39	39	39
Total catch (tonnes)	464000	464000	464000	464000
M ($year^{-1}$)	0.18	0.18	0.18	0.18
F_{MSY}/M	0.8	0.8	0.8	0.8
B_{MSY}/B_0	0.4	0.4	0.4	0.4
Bounds $Bmsy/B_0$	0.6-0.3	0.6-0.3	0.6-0.3	0.6-0.3
		Output		
Median DCAC	8600	8300	7900	7800
Monte Carlo 95% CI of MSY	6400_9700	5900-9500	5600-9400	5200-9200

DCAC estimated that the blue ling stock may sustain a yield of about 8000 tonnes/year. Recent landings have been below this level since 2003 and are about half this level in recent years. The stock is understood as having been overexploited in the past (ICES 2011a) and current landings are constrained by TAC and other management measures. The perception of overexploitation and subsequent ICES advices in the 1990s and 2000s is in line with a MSY higher than current landings, which probably reflects a fishing mortality, below F_{MSY} applied to a stock biomass below B_{MSY}.

Blackspot seabream in Subareas VI, VII and VIII

This stock collapsed in the 1980s (ICES 2011a, Lorance 2011). No assessment has been carried out by ICES in the 1990s-2000s. At the current low level, the stock is not caught in significant numbers by surveys. However, past catches in surveys when the stock was still abundant, suggest that a recovery would be tractable by existing surveys, i.e. bottoms trawls surveys in the Bay of Biscay and Celtic Sea, so the potential category 4. The current, where the only data is a landings time-series going back to the early 1900s and life history traits implies a classification in category 6. There is no sampling in recent year, in relation to the low level of landings and rare catch in surveys. The fishery is currently limited with a TAC of 215 tonnes, mostly caught in Division VIIIc, Cantabrian Sea and a minimum landing size of 35 cm. The current TAC is small compared to historical landings, i.e. ca 20000 t/years in the 1960s-70s (Figure 3.2.2.1). The objective on the DCAC runs are to assess what level of catch could have been sustained by this stock, under the fishing pattern applied at the time, i.e. including catch of one year old fish. There is no need for assessment until some start of recovery is perceived.

Using the long time-series of landings data available for this stock, DCAC was run for several ranges of years (Table 3.2.2.2). Because the collapse in the 1980s for this stock is very clear, the biomass in the 1990s and 2000s can be safely assumed to be in a range of 1-5% of B_0 and the assumptions can be based on the likely level of biomass at the starting years. The following assumptions were made:

- Assumption 1 (table 3.2.2.2): in the early 1900s, the stock was lightly exploited, *B at or above* 95%B_0, Δ may have been 90% or 95% over 1905-2009
- Assumptions 2 and 3: in 1950, the stock was high with some rebuilding having occurred during WW II (Letaconnoux, 1948), then the biomass could have been only slightly lower than in the 1900s, i.e. over 90%B_0. Depletions of 90% assumed over 1950-2009 (Assumption 2) and over 1950-1990 (Assumption 3).
- Assumptions 4-8: the stock got fully exploited, i.e. B=50%B_0, in the early 1960s, depletion of 50% assumed from 1950 until either 2009, 1990 or 1980.

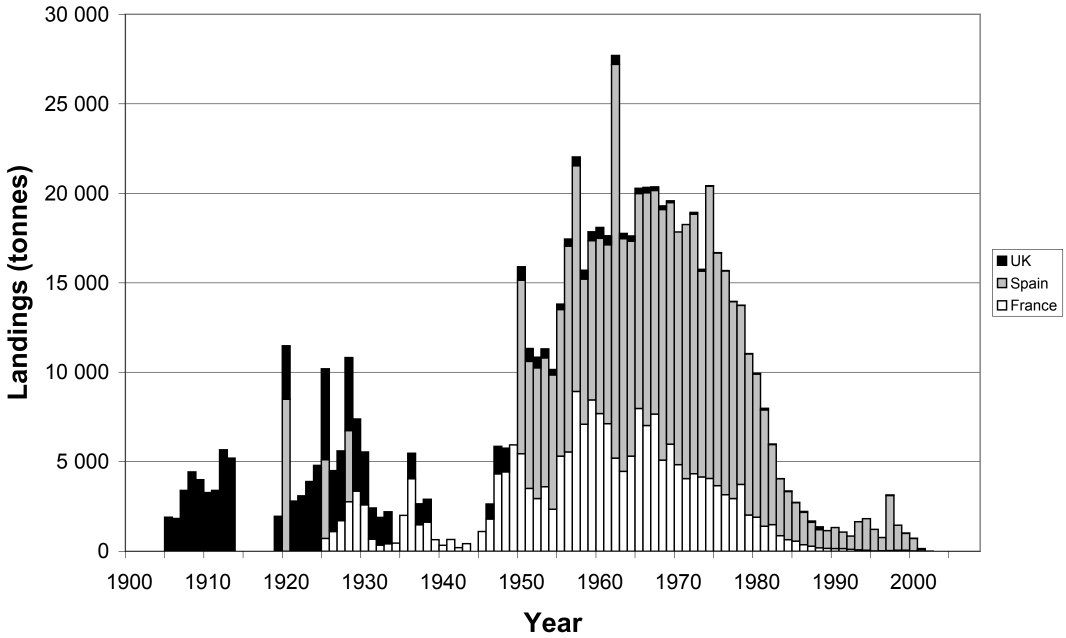

Figure 3.2.2.1. Landings of blackspot seabream in ICES Subareas VI, VII and VIII (Lorance 2011).

Table 3.2.2.2. DCAC output for blackspot seabream

	Input					
Assumption	1	2	3	4	5	6
Depletion *Δ (St Dev.)*	0.95 (0.1)	0.90 (0.1)	0.90 (0.1)	0.50 (0.1)	0.50 (0.1)	0.50 (0.1)
Years	1905-2009	1950-2009	1950-1990	1962-2009	1962-1990	1962-1980
Nb years	105	60	41	48	29	19
Total catch (tones)	713 000	564 000	549 000	382 000	367 000	335 000
M (St Dev)			0.2 (0.5)			
F_{MSY}/M			0.8 (0.2)			
B_{MSY}/B_0			0.4 (0.1)			
Bounds of B_{MSY}/B_0			0.5-0			
Median DCAC (tonnes)	5830	7380	9570	6700	9660	11900
Monte Carlo 95% CI	4680-6380	5380-8490	6400-11580	5210-7440	6760-11350	7570-14600

Total catch were taken as certain. Distributions of F_{MSY}/M and Δ set normal

The sensitivity of the estimated DCAC to Δ was further estimated by varying Δ for the year ranges 1950-1990 and 1962-1980

Table 3.2.2.3. Range of sustainable yield, estimated from the period 1950-1980 (31 years), all parameters set as in Table xx.1 except Δ

Depletion Δ (St Dev.)	0.5 (0.1)	0.6 (0.1)	0.7 (0.1)	0.8 (0.1)	0.9 (0.1)
Median DCAC	12920	12340	11800	11400	10900
Monte Carlo 95% CI of MSY	9190-15050	8470-14700	7860-14400	7300-14100	6820-13800

Table 3.2.2.4. Range of sustainable yield, estimated from the period 1962-1980, all parameter set a in assumption 6 (Table xx.1) except Δ

Depletion Δ (St Dev.)	0.3 (0.1)	0.4 (0.1)	0.5 (0.1)	0.6 (0.1)	0.7 (0.1)
Median DCAC	13800	12500	11900	11000	10500
Monte Carlo 95% CI of MSY	9600-16250	8460-15600	7570-14600	6840-14500	6300-14000

The DCAC estimate is smaller when a range of year after depletion when the stock has no more production is included (Table 3.2.2.2). This explains the higher DCAC under assumption 6 than under 4 and 5. Similarly the lowest DCAC is obtained under assumption 1 when a period of light exploitation (including year with missing reported landings) at the beginning and the 1990s and 2009 where the stock was depleted are included. Then is it recommended to run DCAC over periods with good landings data and where depletion occurs.

Similar DCAC are found over the period 1950-1980 and 1962-1980 (Tables 3.2.2.3 and 3.2.2.4), the range of Δ assumed over these periods (0.3 to 0.9) covers surely the actual depletion. DCAC probably allows considering that the MSY of this stock was about 11000-12000 tonnes. Whether the stock can be rebuilt as level allowing for such a fishery is beyond the scope of WKLIFE. In situation, such a blackspot seabream where a strong depletion is known to have occur with quite reliable catch data, DCAC allows for an estimation, which may be used as an absolute MSY reference point. However, the MSY derived from DCAC, remain conditional to the fishing pattern during the depletion period.

Orange roughy in ICES Subarea VI

Orange roughy was categorized 6 or 7 i.e. landings data. This applies to orange roughy in Subarea VI. In Subarea VII addition data are available such as an acoustic estimated from a survey carried out in the 2000s (see ICES 2011a), however, the only time-series available for this species are landings. Experience from New Zealand waters have shown that little of no changes demographic pattern (i.e. mean length in the catch) with exploitation are seen for this species.

The fishery in European waters is closed following ICES advice that the species got depleted. DCAC was used to assess possible sustainable catch level in Subarea VI. The time-series of landing for 1991 to 2005 (ban of the fishery from 2006) sums up to 7200 tonnes. The natural mortality is estimated to be about 0.05 for orange roughy. DCAC was run with and F_{MSY} to M ratio of 0.8, a B_{MSY} to B_0 ratio of 0.4 and a depletion Δ of 0.9. St. Dev were set at the same levels as for blue ling and bblackspot seabream.

DCAC was estimated at 88 tonnes.yr^{-1} (95% CI 35 - 182). Further runs were not done, small variations in DCA could be obtained by varying the depletion Δ and other parameters. It should be noted that this approach, should be considered as reprenseting what could have been the sustainable yield on orange roughy on fishing grounds were the standing biomass was depleted to low level. In Division VI, this is likely to represent quite closely the actual depletion of the biomass along the West of Scotland slope. It is less clear if there was orange roughy on other grounds of Subarea VI, e.g. the around the Rockhall Bank and whether it was depleted in all locations.

In Subareas VII, it makes no doubt that significant orange roughy biomass remain in some locations. Therefore applying DCAC with a depletion level of 0.9 in Subarea VII would strictly represent the depletion on exploited fishing grounds but would not inform on the remaining biomass in other areas. An acoustic estimation of this biomass was tried in 2005 when an acoustic survey was carried out on the slopes to the west and north of the Porcupine Bank. Estimates of biomass were considered to be unreliable due to concerns over target strength (ICES 2011a).

3.2.3 Application of the Catch-MSY method

Participants at the workshop filled in spreadsheets with life-history information and catch data for selected data-rich and data-poor ICES stocks. These life-history entries were then compared with parameter estimates from various empirical equations, for detection of unlikely values. The main goal here was to get reasonable estimates of the von Bertalanffy growth parameter *K* and of natural mortality *M*. These estimates were then used to set a lower limit for the prior range of *r*, an input value that mildly influences the resulting estimates of *MSY* but strongly influences the estimates of *r* and *k* resulting from the Catch-MSY method.

If no other information was given, the Catch-MSY method assumed that biomass at the start of the time series of catches was 0.5 *k* (i.e. 50% depletion), and that biomass at the end of the time series was in the range of 0.01 *k* to 0.6 *k* (40%–99% depletion). Random samples of the carrying capacity parameter (*k*) were then drawn from a uniform distribution where the lower and upper limits were given by the maximum catch in the time series and 100 times maximum catch, respectively.

As most probable values from the resulting density distributions the Catch-MSY method uses the geometric means of *r*, *k*, and *MSY*, where *MSY* is calculated from the viable *r-k* pairs (see Appendix I). As measure of uncertainty the Catch-MSY method uses two times the standard deviation of the logarithmic mean. This implies that, with a roughly log-normal distribution, about 95% of the *MSY* estimates would fall within this range.

If no prior information for *r* was given, resilience estimates from FishBase were used. These are based on Musick (1999) as modified by Froese *et al*. (2000), and assign ranges of the maximum intrinsic rate of population increase *r* to species, according to known values for other life history traits (Table 3.2.3.1).

Table3.2.3.1. Default values used by the Catch-MSY method, based on resilience assignments in FishBase, where *K* is the von Bertalanffy growth parameter, t_m is the age at 50% maturity, t_{max} is the maximum age, and *r* is the resulting range of the maximum intrinsic rate of population increase. Assignment to a resilience category is based on the lowest match with existing life history data. For example, an average annual fecundity of less than 10 pups would put a species into the Very low resilience category, even if its maximum age would put it into the Medium resilience category.

Resilience	High	Medium	Low	Very low
K (1/year)	> 0.3	0.16 – 0.3	0.05 – 0.15	< 0.05
t_m (years)	< 1	2 – 4	5 – 10	> 10
t_{max} (years)	1 – 3	4 – 10	11 – 30	> 30
Fecundity (n/year)	> 10,000	100 – 1000	10 – 100	< 10
r ($year^{-1}$)	0.6 – 1.5	0.2 – 1	0.05 – 0.5	0.015 – 0.1

Blue Ling

An example of the data collection spreadsheet for the Blue Ling (*Molva dypterygia*, bli-comb) is shown in Table 3.2.3.2. For the Catch-MSY analysis, a prior range for *r* was chosen as *r* = 0.18 – 1, where 0.18 was taken from the estimate for natural mortality, which in a given population should be smaller than *r*. The upper range for *r* was set to 1. The population was largely unexploited at the beginning of the time series, so the relative biomass at that point was set to 0.9 k. The population was overfished in 2004, so an intermediate biomass range of 0.01 – 0.4 *k* was set for that year. The stock recovered thereafter, so a final biomass range of 0.1 – 0.4 *k* was set for the year after the last catch.

A variety of empirical equations was used to contrast the provided information and to detect potential outliers, see Table 3. This exercise was meant to increase confidence in the prior information. It also helped to get a feeling where the stock abundance may have been at the beginning and the end of the time series of catches. Running the Catch-MSY analysis with the input shown in Table 3.2.3.2 plus catch data resulted in an *MSY* estimate with confidence limits that seemed appropriate for this stock, given that catches above that level preceded the known decline in biomass below B_{msy}. F_{msy} = ½ *r* = 0.12 (0.09 – 0.165) is slightly lower than a previous estimate F_{msy} = 0.144 which was based on the rule of thumb that F_{msy} = 0.8 *M* and recent *M* estimates.

Table 3.2.3.2. Life history data for Blue Ling in ICES Vb, VI, VII and XII, with Inputs used for the Catch-MSY method and results from running the analysis.

Species	*Molva dypterygia*	Specific name, e.g. morhua
Common name	Blue ling	Common name used in assessment, e.g. Atlantic Cod
Stock area	ICES Vb, VI, VII and XII	Detailed definition of stock area, e.g. "North Sea, IV, VIId and IIIa"
Stock-ID	bli-comb	Code used for this stock, e.g. cod-347d
Resilience	Low	High, Medium, Low, or Very Low, see Table 1.
Lmax (cm)	148	Maximum length known for this stock, e.g. 120
Lm (cm)	85	Length where 50% of the larger sex reach maturity, e.g. 40
Lc (cm)	90	Length that is fully selected by the gear, e.g. 35
Lmean (cm)	90.2	Recent mean length in the catch, e.g. 48.5
Wmax (g)	19600	Maximum weight known for fish from this stock, e.g. 23000
Wmean (g)	4566	Mean weight in catch, e.g. 1120
tmax (years)	25	Maximum age known for the stock, e.g. 15
tm (years)	9	Age where >=50% of the larger sex reach maturity, e.g. 4
tc (years)	9	Age that is fully selected by the gear, e.g. 2
M (1/year)	0.18	Adult mortality rate, e.g. 0.26
Fmsy (1/year)	0.144	Best estimate (guess) for F that will produce MSY, e.g. 0.19
F [year]	0.1	Best estimate of recent F, e.g. 0.68 [2010]
F / Fmsy	Below	Best guess whether recent F is below, around, or above Fmsy.
CPUE trends	increasing	Broad recent trends in catch per unit effort
B / Bmsy	below	Best guess whether recent biomass is below, around, or above Bmsy.
Linf (cm)	140	asymptotic length, VBGF parameter, e.g. 110
VBGF K (1/year)	0.13	rate of growth, VBGF parameter, e.g. 0.13

to (year)	1	age at zero length, VBGF parameter, e.g., -0.2
Phi'	3.41	Index derived from Linf and K.
a	0.00116	parameter of length-weight relationship, e.g. 0.01
b	3.273	parameter of length-weight relationship, e.g. 3.0
Input for Catch-MSY method		
prior range for *r*	0.18 - 1	
1st B / k	0.9	Best guess of biomass / carrying capacity ratio at first year of catch data, default 0.5
last+1 B / k range	0.1 - 0.4	Best guess of B/k range after last year with catch data, e.g. 0.01 - 0.1, default 0.01 - 0.6
intermediate B / k range [year]	0.01 - 0.4 [2004]	Best guess of intermediate B/k range, e.g. 0.01-0.3 [1992], default none
Output of Catch-MSY method		
MSY (+/- 2 SD)	11,649 (10,495 – 12,930)	
r (+/- 2 SD)	0.24 (0.18 - 0.33)	
k (+/- 2 SD)	193,257 (155,267 – 240,544)	

Table 3.2.3.3. Comparison between provided life history traits and predictions from empirical equations.

Correlations and empirical equations, for cross-checking of provided data.	
M as provided	0.18
Mean temperature T (C°)(needed for next)	10
VBGF (Pauly 1980)	0.19
from tmax (Hoenig 1984)	0.18
from VBGF K (Jensen 1996)	0.20
from Gislason (submitted)	0.27
F as provided	0.1
F from VBGF, M, tc, Lmean	-20.65
F from VBGF, M, Lc, Lmean	32.19
tmax as provided	25
age at 0.95 Linf (Taylor 1958)	24.0
from tm (Froese and Binohlan 2000)	29.0
Linf as provided	140
from Lmax (Froese and Binohlan 2000)	151.3
Lmax as provided	148.0
from Lm (Binohlan and Froese 2009)	131.6
from maximum weight	161.6
VBGF K as provided	0.13
from tmax (Taylor 1958)	0.12
from Lmax, using Phi' (Pauly et al. 1998)	0.11
Lm as provided	85
from Linf (Froese and Binohlan 2000)	82.4
Lmean as provided	90.2
from B&H 1957, using VBGF, tc, M, F	106.2
from B&H 1957, using VBGF, Lc, M, F	105.9
from mean weight in catch and LWR	103.5
Holt (1958)	95.8
Froese and Binohlan (2000)	91.7
Froese et al. (2008)	93.3

Mean length in the catch sensu Beverton and Holt (1957) was compared with the mean length if von Bertalanffy $K \sim 2/3\ M$ and $F = M$, a new simplification proposed by Froese (in prep), viz.

$$L_{F=M} = \frac{3L_c + L_\infty}{4}$$

The provided mean length of 90.2 cm was slightly lower than the mean length where $F = M = 102.5$, leading to the conclusion that recent F in this stock was probably above F_{msy}. This was not true for the very last year, where $F = 0.1$ was below the prior $F_{msy} = 0.144$. However, it was true if a mean of F values over the last years was taken. The number of recent years to be considered for such mean F will be related to generation time, for which age at maturity (here 9 years) can be taken as a minimum proxy.

The mean-length-in-catch equation of Beverton and Holt (1957) can also be solved for F, with mean length and either age (t_c) or length (L_c) at full selection by the gear as inputs. Because the mean length L_{mean} = 90.2 was very close to L_c = 90, highly unrealistic estimates of F resulted (see Table 3.2.3.3). It turned out that the provided estimate of L_{mean} included specimens smaller than L_c (or younger than t_c). This was also the case in other contributions at the workshop, so it is stressed here that for application of the B & H mean length in catch equation, only specimens with $L >= L_c$ and age $<= t_c$ may be included in the calculation of the weighted mean, weighted by the numbers in the respective length and age classes. The corresponding mean length for blue ling was L_{mean} = 99.8 cm, giving a predicted F = 0.38 from the L_c and 0.35 from the t_c equation. These equations are valid under the equilibrium assumption, which is not valid for blue ling, because TACs have been reduced over the period 2003-2010 driving F down and higher recruitment has been observed since 2007 than in 2000-2006. To somewhat account for such changes, the F estimates from mean length should not be compared with last year's F, but rather with a mean F over several recent years, equivalent to generation time.

For blue ling the generation time is estimated as 9.6 years (see next paragraph). The mean F over the last 10 and 9 years based on a multi-year catch curve model developed in the DEEPFISHMAN project are 0.22 and 0.25 respectively, i.e., lower than the values derived from the L_{mean} equation. It should be noted than these latter results are preliminary. Further, the change in L_{mean} from 90.2 to 99.8 cm is a 10% change, or a change of only 7% L_∞, suggesting that this method is sensitive to L_{mean} estimates. Therefore either accurate length data are required, which is considered to be the case for blue ling, or confidence intervals or sensitivity estimates should be included in the method.

Froese et al. (2000) present the following reasoning for calculation of generation time: "Generation time [..] is the average age (t_g) of parents at the time their young are born. In most fishes L_{opt} [..] is the size class with the maximum egg production (Beverton 1992). The corresponding age (t_{opt}) is a good approximation of generation time in fishes. It is calculated using the parameters of the von Bertalanffy growth function as $t_g = t_{opt} = t_0 - \ln(1 - L_{opt} / L_{inf}) / K$." For fishes with isometric growth (b~3), generation time can be estimated from $t_{opt} = 1.099 / K + t_0$. Alternatively, generation time can be approximated from the age at 50% maturity of the later maturing sex, plus the mean duration of adult life expectancy, which is given by $1/M$ (Charnov 1993).

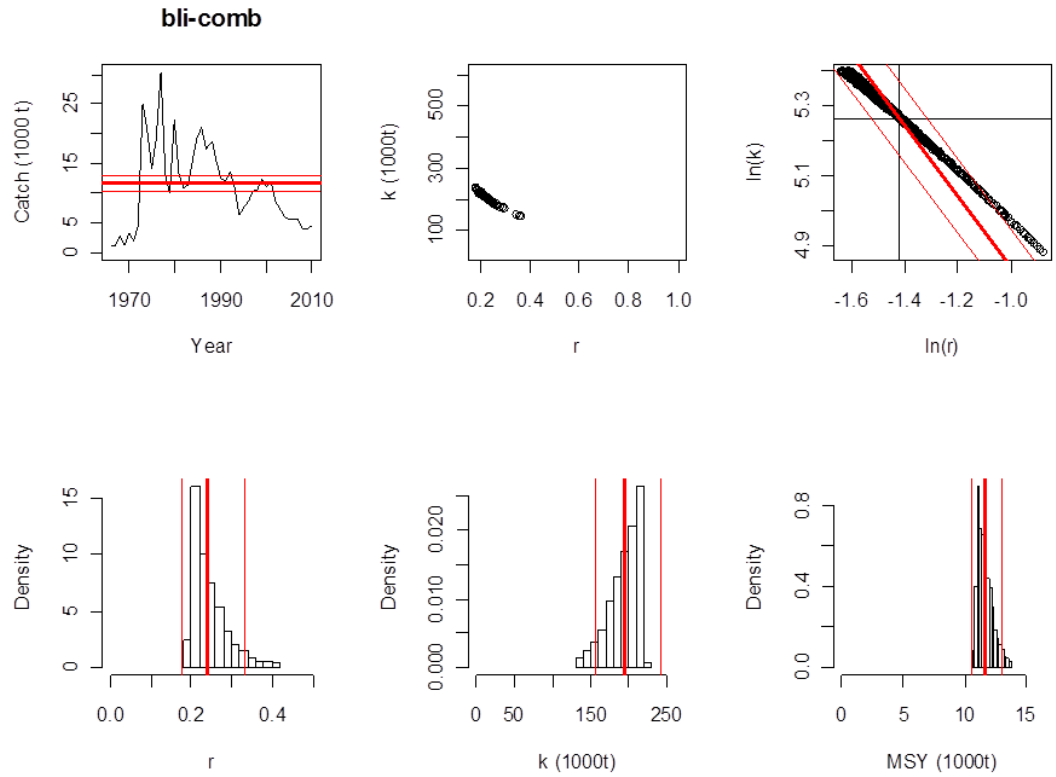

Figure 3.2.3.1. Graphic output of a Catch-MSY analysis for the Blue Ling. The upper-left panel shows the catch time series with overlaid lines for *MSY* +/- 2 standard deviations. The upper-middle panel shows the prior *r-k* space and the viable *r-k* pairs. The upper right panel shows the viable *r-k* pairs in log space, with overlaid estimates of *MSY* +/- 2 SD. The lower panels show the density distributions of *r*, *k* and *MSY*, with indicated geometric means +/- 2 SD.

Blackbelly eelpout

Another example was a lightly exploited by-catch species, the Blackbelly eelpout *Lycodes pacificus* in the Eastern Pacific management area WCVI. Input data were prior *r* = 0.3 – 1, relative stock size in first year 0.9 *B/k*, range of relative biomass in last year 0.9 – 1 *B/k*. Thus, exploitation only took a small portion of the biomass, and a very wide range of *r-k* pairs are compatible with these catches. These data cannot be used for estimation of *MSY*.

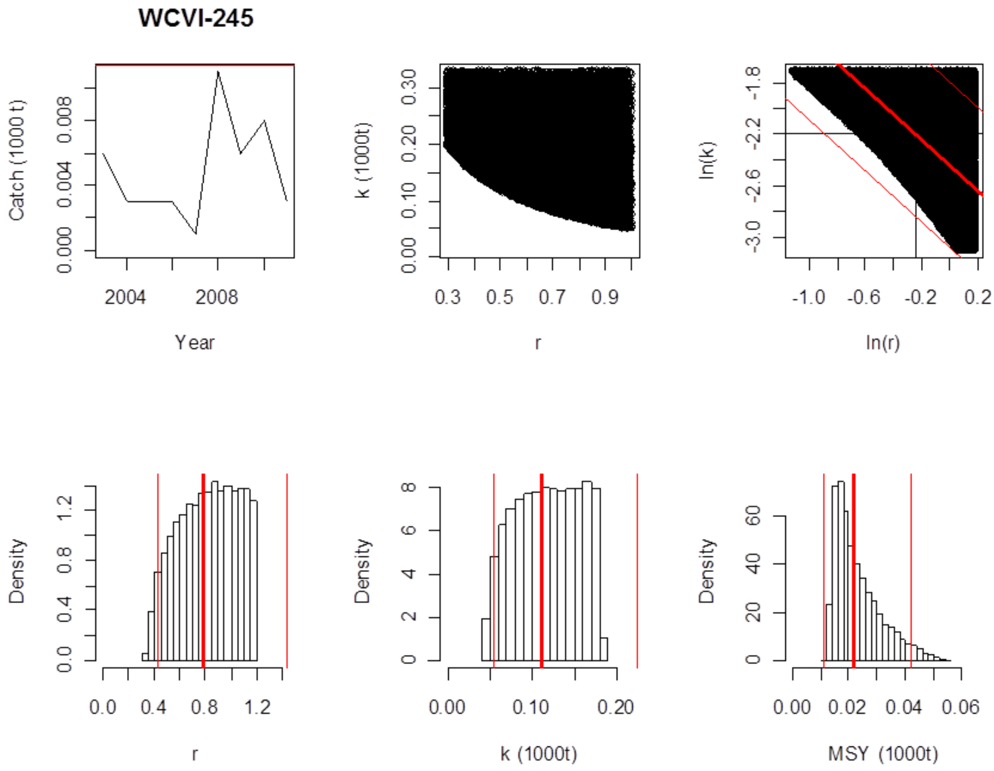

Figure 3.2.3.2. Graphical output of the Catch-MSY method applied to Blackbelly Eelpout. By-catch levels are very low and the population is estimated to be near the unexploited level. Therefore, no meaningful estimates of *MSY*, *r* and *k* can be obtained.

It was stressed at the workshop that the general rules for production models should also apply to the Catch-MSY method, i.e. the input data must be reasonable (the garbage in–garbage out rule obviously applies) and the biomass of the considered stock should preferably have gone through a depletion and recovery phase, not be monotone stable, decreasing or increasing. The general rule applies that response of a stock to exploitation cannot be understood unless the stock has been fully exploited (e.g. Hilborn and Walters 1992).

3.2.4 Follow-up to the workshop meeting: Catch-MSY versus DCAC

In the email discussion following the workshop, the question was raised why sustainable catch estimates from the depletion-corrected average catch method of MacAll (2009) give lower estimates than *MSY* estimated with the Catch-MSY method. Quoting the first sentences of MacCall (2009) to clarify this issue: "Unlike the classic fishery problem of estimating maximum sustainable yield (*MSY*), data-poor fishery analysis must often be content simply to estimate a yield that is likely to be sustainable. Although absurdly low yield estimates would have this property, they are of little practical use. Here, the problem is to identify a moderately high yield that is likely to be sustainable, while having a low probability that the estimated yield level greatly exceeds *MSY* [..]." Thus, one would expect DCAC to give significantly lower estimates of sustainable catch than *MSY* estimated by the Catch-MSY method or other methods. This was the case for blue ling, where DCAC estimated a sustainable catch of 8,845 (6924 – 10,140) t, whereas the Catch-MSY method gave the maximum sustainable catch as MSY = 11,649 (10,495 – 12,930).

3.2.5 Lessons for the categorization of stocks

WKLIFE was designed to define reference points for stocks where only LHTs are available. The process of stock categorization revealed that for most stocks covered by sub-group 1 much more data are available. These included:

- DCF data, e.g. length and age structure for many stock;
- commercial CPUE trends;
- times-series of landings data, some of which may be long with good reliability. For example, deep-water species tend to be caught by target fisheries. On the one-hand large offshore trawlers have been reporting catch for long, i.e. starting well before EU-logbooks and landings have mainly gone through auction market so that track records may be more reliable than for some coastal species caught as bycatch in several fisheries. On the other hand, artisanal fisheries for deep-water species such as longlining for black-scabbardfish off Portugal and blackspot seabream in the Strait of Gibraltar, involved well identified fleets, landings into one or a few ports only. As a result, these stocks have rather long and reliable catch records appropriate for some modeling; e.g. DCAC.
- survey times-series are available for a number of by-catch species considered by subgroup 1 e.g. gurnards and flatfishes.

Two different issues are (1) the use of all available data by assessment expert groups. It appeared that in some cases available data are not used, which may have a number of reasons, e.g. insufficient human resources, knowledge of experts about data availability in other countries, agencies, etc…, delays between data collection and availability to, for example, ICES or web-based facilities.

Some assessments are carried out by experts groups and not used for advice. These assessments may not be fully reliable, e.g. statistical properties not good, inconsistencies or may provide only parts of the desired information. However, there is probably more information available for advice than that currently used.

With respect to ToR d) some data are not included in ICES' assessments and work is needed to investigate how to incorporate them, including by developing new models.

4 Sub-group II: WGNSSK, WGCSE, WGHMM and SECR stocks

The 45 stocks from WGCSE, WGHMM, and WGNSSK which do not have an advice based on a population estimate were examined.

4.1 Proxies for F_{MSY} based on life-history traits (ToR a and d)

An attempt was made to populate a table with basic life-history parameters for these stocks (Table 4.1.1). As many of the parameters were length based, and the EG's primarily deal with age structured information, in many cases FishBase was used as a reference source from which to get values. Where FishBase was used, it was found that in many cases there are a wide range of results available. It was not possible to determine the appropriateness of any of these studies without digging into the literature, a rough rule of thumb was to look for a contemporary study with as close as possible geographic range and well supported with data. In any event the source for the information is noted, as the exercise was just to see if values could be obtained.

In order to make these parameters operational for advice generation purposes, the EG's would be the appropriate forum to populate these tables.

The quick overview produced at WKLIFE determined that growth parameters could be obtained for 31 out of the 45 stocks, and maturity information for 28 (see Table 4.1.1.). Using the method described in Section 2.1.1 (Le Quesne code), the basic life history parameters were used to generate reference points (assuming knife edge selection at age 1 or age 2) F0.1, Fmax, and SPR reference points of F10, 30, 35 and 40%SPR (Table 4.1.2). General conclusions on the sensitivities and limitations of this approach are given in section 2.1.2.

Table 4.1.1 Life history parameters (L50 - Length at 50% maturity; Lc - length/age at first capture; Length units in mm for *Nephrops*).

Code	Stock name	EG	Lmax (cm)	Linf (cm)	L50 (cm)	K ($year^{-1}$)	t_0 (year)	Lc (cm)	M (study based) close to L50	Source
nep-5	Nephrops in Division IVbc (Botney Gut - Silver Pit, FU 5)	wgnssk			26.5					No Stock Annex
nep-10	Nephrops in Division IVa (Noup, FU 10)	wgnssk								No info
nep-32	Nephrops in Division IVa (Norwegian Deeps, FU 32)	wgnssk								No info
nep-33	Nephrops in Division IVb (Off Horn Reef, FU 33)	wgnssk								No Stock Annex
san-ns4	Sandeel in the Central Western North Sea (SA 4)	wgnssk	22		14			10		North Sea average values based on Danish sampling
san-ns5	Sandeel in the Viking and Bergen Bank area (SA 5)	wgnssk	22		14			10	0.86	North Sea average values based on Danish sampling
san-ns6	Sandeel in Division IIIa East (Kattegat, SA6)	wgnssk	22		14			10		North Sea average values based on Danish sampling
san-ns7	Sandeel in the Shetland area (SA 7)	wgnssk	22		14			10		North Sea average values based on Danish sampling
pol-nsea	Pollack in Subarea IV and Division IIIa	wgnssk	130	85.6		0.186		Age 3		
whg-kask	Whiting in Division IIIa (Skagerrak - Kattegat) LOWER RANGE	wgnssk	65	31	28-30	0.98 - 0.08				
whg-kask	Whiting in Division IIIa (Skagerrak - Kattegat) UPPER RANGE	wgnssk	65	95	28-30	0.98 - 0.08				
ple-kask	Plaice in Division IIIa (Skagerrak - Kattegat) LOWER RANGE	wgnssk	68.5	40	30-35	0.06 - 0.33				
ple-kask	Plaice in Division IIIa (Skagerrak - Kattegat) UPPER RANGE	wgnssk	68.5	81	30-35	0.06 - 0.33				
ple-eche	Plaice in Division VIId (Eastern Channel)	wgnssk	68.5	40	30-35	0.06 - 0.33				
ple-eche	Plaice in Division VIId (Eastern Channel)	wgnssk	68.5	81	30-35	0.06 - 0.33				
ple-7h-k	Plaice in Divisions VIIh-k (Southwest of Ireland)	wgcse		59.4	23	0.11				jennings et al 1998, L50 from WGCSE
ple-7b-c	Plaice in Division VIIb,c (West of Ireland)	wgcse		59.4	28.8	0.11				jennings et al 1998
cod-rock	Cod in Division VIb (Rockall)	wgcse		132		0.2				
whg-scow	Whiting in Division VIa (West of Scotland)	wgcse		56.3	20	0.11				jennings et al 1998, L50 from WGCSE
whg-rock	Whiting in Division VIb (Rockall)	wgcse		45		0.483	-0.42			
ang-ivvi	Anglerfish (*Lophius piscatorius* and *L. budegassa*) in Divisions IIa, IIIa, Subarea IV and VI	wgcse		140.5 **f**		0.177f 0.154m				
ang-ivvi	Anglerfish (*Lophius piscatorius* and *L. budegassa*) in Divisions IIa, IIIa, Subarea IV and VI	wgcse		110.5 **m**		0.177f 0.154m				
had-iris	Haddock in Division VIIa (Irish Sea)	wgcse		68	22	0.16				jennings et al 1998, L50 from WGCSE
nep-16	Nephrops in Division VIIb,c,j,k (Porcupine Bank, FU 16)	wgcse			27.3					No Stock Annex. WKNEPH2006
nep-19	Nephrops in Division VIIa,g,j (South East and West of IRL, FU 19)	wgcse								No Stock Annex. WKNEPH2006
nep-2022	Nephrops in Division VIIf,g,h (Celtic Sea, FU 20-22)	wgcse								No Stock Annex
sol-7h-k	Sole in Divisions VIIh-k (Southwest of Ireland)	wgcse		49.8	23	0.13				jennings et al 1998, L50 from WGCSE
sol-7b-c	Sole in Division VIIb, c (West of Ireland)	wgcse		49.8	21	0.13				jennings et al 1998, L50 from WGCSE
meg-4a6a	Megrim (*Lepidorhombus spp*) in Divisions IVa and VIa	wgcse		54	23	0.12				Jennings et al 1999
meg-rock	Megrim (*Lepidorhombus spp*) in ICES Division VIb (Rockall)	wgcse		54	23	0.12				Jennings et al 1999
had-7b-k	Haddock in Divisions VIIb-k	wgcse		68	30.6	0.16				jennings et al 1998
pol-celt	Pollack in Subareas VI and VII (Celtic Sea and West of Scotland)	wgcse	130	85.6		0.19				
whg-iris	Whiting in Division VIIa (Irish Sea) LOWER RANGE	wgcse	65	31	28-30	0.98 - 0.08				
whg-iris	Whiting in Division VIIa (Irish Sea) UPPER RANGE	wgcse	65	95	28-30	0.98 - 0.08				
whg-7e-k	Whiting in Division VIIe-k LOWER RANGE	wgcse	65	31	28-30	0.98 - 0.08				
whg-7e-k	Whiting in Division VIIe-k UPPER RANGE	wgcse	65	95	28-30	0.98 - 0.08				
ple-iris	Plaice in Division VIIa (Irish Sea) LOWER RANGE	wgcse	100	45	30-35	0.28 - 0.06				
ple-iris	Plaice in Division VIIa (Irish Sea) UPPER RANGE	wgcse	100	81	30-35	0.28 - 0.06				
ple-celt	Plaice in Divisions VIIf,g (Celtic Sea)	wgcse	68	59	30-35	0.11				
mgw-78	Megrim (*Lepidorhombus whiffiagonis*) in Divisions VIIb-k and VIIIa,b,d	wghmm								
ang-78ab	Anglerfish (*Lophius piscatorius* and *L. budegassa*) in Divisions VIIb-k and VIIIa,b,d LOWER RANGE	wghmm	162	106	35-60	0.18 - 0.08				
ang-78ab	Anglerfish (*Lophius piscatorius* and *L. budegassa*) in Divisions VIIb-k and VIIIa,b,d UPPER RANGE	wghmm	162	167	35-60	0.18 - 0.08				
nep-25	Nephrops in North Galicia (FU 25)	wghmm	80	70	28	0.16		25	0.2	Stock Annex (males; mm CL; Lmat females
nep-31	Nephrops in the Cantabrian Sea (FU 31)	wghmm		85		0.15			0.2	No Stock Annex. WGNEPH2002 (males; mm CL)
nep-2627	Nephrops in West Galicia and North Portugal (FU 26-27)	wghmm	70	80	26	0.15		20	0.2	Stock Annex (males; mm CL; Lmat females
nep-2829	Nephrops in South-West and South Portugal (FU 28-29)	wghmm	79	70	30	0.2		23	0.3	Stock Annex (males; mm CL; Lmat females
nep-30	Nephrops in Gulf of Cadiz (FU 30)	wghmm	62	60	28	0.16		17	0.2	Stock Annex (males; mm CL; Lmat females
sol-8c9a	Sole in Divisions VIIIc and IXa	wghmm	100 **SL**	59.4	28.8	0.11				No Stock Annex. Celtic Sea UK
ple-89a	Plaice in Subarea VIII and Division IXa	wghmm	70 **SL**	54.6		0.47				No Stock Annex. Tagus Estuary
pol-89a	Pollack in Subarea VIII and Division IXa	wghmm	130	85.6		0.19			0.55	No Stock Annex. Southern Ireland
whg-89a	Whiting in Subarea VIII and Division IXa	wghmm	70	70		0.19			0.34	No Stock Annex. Females BB, M from Scotland
nop-scow	Norway pout in Division VIa	secr								
san-scow	Sandeel in Division VIa	secr								
	f - females; m - males; SL - Standard Length									

Table 4.1.2 Fishing mortality reference points assuming knige-edge recruitment to the fishery at age 1 (ACF1) and at age 2 (AFC2).

Code	Stock name	EG	'AFC1-Fmax'	'AFC1-F0.1'	'AFC1-F30'	'AFC1-F35'	'AFC1-F40'	'AFC1-F10'	AFC2-Fmax	'AFC2-F0.1'	'AFC2-F30'	'AFC2-F35'	'AFC2-F40'	'AFC2-F10'
nep-5	Nephrops in Division IVbc (Botney Gut - Silver Pit, FU 5)	wgnssk	*	*	*	*	*	*	*	*	*	*	*	*
nep-10	Nephrops in Division IVa (Noup, FU 10)	wgnssk	*	*	*	*	*	*	*	*	*	*	*	*
nep-32	Nephrops in Division IVa (Norwegian Deeps, FU 32)	wgnssk	*	*	*	*	*	*	*	*	*	*	*	*
nep-33	Nephrops in Division IVb (Off Horn Reef, FU 33)	wgnssk	*	*	*	*	*	*	*	*	*	*	*	*
san-ns4	Sandeel in the Central Western North Sea (SA 4)	wgnssk	1.01	0.5	0.51	0.43	0.37	1.16	1.37	0.63	1.21	0.95	0.76	2
san-ns5	Sandeel in the Viking and Bergen Bank area (SA 5)	wgnssk	1.01	0.5	0.51	0.43	0.37	1.16	1.37	0.63	1.21	0.95	0.76	2
san-ns6	Sandeel in Division IIIa East (Kattegat, SA6)	wgnssk	1.01	0.5	0.51	0.43	0.37	1.16	1.37	0.63	1.21	0.95	0.76	2
san-ns7	Sandeel in the Shetland area (SA 7)	wgnssk	1.01	0.5	0.51	0.43	0.37	1.16	1.37	0.63	1.21	0.95	0.76	2
pol-nsea	Pollack in Subarea IV and Division IIIa	wgnssk	0.24	0.15	0.16	0.13	0.11	0.35	0.32	0.17	0.19	0.16	0.13	0.45
whg-kask	Whiting in Division IIIa (Skagerrak - Kattegat) LOWER RANGE	wgnssk	0.74	0.38	0.38	0.32	0.28	0.85	1.05	0.47	0.64	0.53	0.44	2
whg-kask	Whiting in Division IIIa (Skagerrak - Kattegat) UPPER RANGE	wgnssk	0.22	0.13	0.14	0.12	0.1	0.32	0.28	0.15	0.16	0.14	0.12	0.39
ple-kask	Plaice in Division IIIa (Skagerrak - Kattegat) LOWER RANGE	wgnssk	0.55	0.29	0.3	0.25	0.22	0.67	0.8	0.36	0.43	0.36	0.3	1.16
ple-kask	Plaice in Division IIIa (Skagerrak - Kattegat) UPPER RANGE	wgnssk	0.26	0.15	0.16	0.14	0.12	0.37	0.34	0.18	0.2	0.17	0.14	0.47
ple-eche	Plaice in Division VIId (Eastern Channel)	wgnssk	0.55	0.29	0.3	0.25	0.22	0.67	0.8	0.36	0.43	0.36	0.3	1.16
ple-eche	Plaice in Division VIId (Eastern Channel)	wgnssk	0.26	0.15	0.16	0.14	0.12	0.37	0.34	0.18	0.2	0.17	0.14	0.47
ple-7h-k	Plaice in Divisions VIIh-k (Southwest of Ireland)	wgcse	0.36	0.2	0.21	0.18	0.15	0.48	0.5	0.24	0.27	0.23	0.19	0.67
ple-7b-c	Plaice in Division VIIb,c (West of Ireland)	wgcse	0.36	0.2	0.21	0.18	0.15	0.48	0.5	0.24	0.27	0.23	0.19	0.67
cod-rock	Cod in Division VIb (Rockall)	wgcse	0.15	0.1	0.11	0.09	0.08	0.24	0.19	0.11	0.12	0.1	0.09	0.28
whg-scow	Whiting in Division VIa (West of Scotland)	wgcse	0.38	0.21	0.22	0.19	0.16	0.5	0.53	0.25	0.29	0.24	0.21	0.73
whg-rock	Whiting in Division VIb (Rockall)	wgcse	0.48	0.26	0.27	0.23	0.2	0.61	0.7	0.32	0.38	0.32	0.27	0.99
ang-ivvi	Anglerfish (*Lophius piscatorius* and *L. budegassa*) in Divisions IIa, IIIa, Subarea IV and VI	wgcse	0.14	0.09	0.1	0.09	0.07	0.23	0.17	0.1	0.11	0.1	0.08	0.27
ang-ivvi	Anglerfish (*Lophius piscatorius* and *L. budegassa*) in Divisions IIa, IIIa, Subarea IV and VI	wgcse	0.18	0.11	0.12	0.11	0.09	0.28	0.23	0.13	0.14	0.12	0.1	0.34
had-iris	Haddock in Division VIIa (Irish Sea)	wgcse	0.31	0.18	0.19	0.16	0.14	0.43	0.42	0.21	0.24	0.2	0.17	0.58
nep-16	Nephrops in Division VIIb,c,j,k (Porcupine Bank, FU 16)	wgcse	*	*	*	*	*	*	*	*	*	*	*	*
nep-19	Nephrops in Division VIIa,g,j (South East and West of IRL, FU 19)	wgcse	*	*	*	*	*	*	*	*	*	*	*	*
nep-2022	Nephrops in Division VIIf,g,h (Celtic Sea, FU 20-22)	wgcse	*	*	*	*	*	*	*	*	*	*	*	*
sol-7h-k	Sole in Divisions VIIh-k (Southwest of Ireland)	wgcse	0.44	0.24	0.25	0.21	0.18	0.57	0.63	0.29	0.34	0.29	0.24	0.88
sol-7b-c	Sole in Division VIIb, c (West of Ireland)	wgcse	0.44	0.24	0.25	0.21	0.18	0.57	0.63	0.29	0.34	0.29	0.24	0.88
meg-4a6a	Megrim (*Lepidorhombus spp*) in Divisions IVa and VIa	wgcse	0.4	0.22	0.23	0.2	0.17	0.52	0.57	0.27	0.3	0.26	0.22	0.76
meg-rock	Megrim (*Lepidorhombus spp*) in ICES Division VIb (Rockall)	wgcse	0.4	0.22	0.23	0.2	0.17	0.52	0.57	0.27	0.3	0.26	0.22	0.76
had-7b-k	Haddock in Divisions VIIb-k	wgcse	0.31	0.18	0.19	0.16	0.14	0.43	0.42	0.21	0.24	0.2	0.17	0.58
pol-celt	Pollack in Subareas VI and VII (Celtic Sea and West of Scotland)	wgcse	0.24	0.15	0.16	0.13	0.11	0.35	0.32	0.17	0.19	0.16	0.13	0.45
whg-iris	Whiting in Division VIIa (Irish Sea) LOWER RANGE	wgcse	0.74	0.38	0.38	0.32	0.28	0.85	1.05	0.47	0.64	0.53	0.44	2
whg-iris	Whiting in Division VIIa (Irish Sea) UPPER RANGE	wgcse	0.22	0.13	0.14	0.12	0.1	0.32	0.28	0.15	0.16	0.14	0.12	0.39
whg-7e-k	Whiting in Division VIIe-k LOWER RANGE	wgcse	0.74	0.38	0.38	0.32	0.28	0.85	1.05	0.47	0.64	0.53	0.44	2
whg-7e-k	Whiting in Division VIIe-k UPPER RANGE	wgcse	0.22	0.13	0.14	0.12	0.1	0.32	0.28	0.15	0.16	0.14	0.12	0.39
ple-iris	Plaice in Division VIIa (Irish Sea) LOWER RANGE	wgcse	0.48	0.26	0.27	0.23	0.2	0.61	0.7	0.32	0.38	0.32	0.27	0.99
ple-iris	Plaice in Division VIIa (Irish Sea) UPPER RANGE	wgcse	0.26	0.15	0.16	0.14	0.12	0.37	0.34	0.18	0.2	0.17	0.14	0.47
ple-celt	Plaice in Divisions VIIf,g (Celtic Sea)	wgcse	0.36	0.21	0.21	0.18	0.16	0.48	0.51	0.25	0.28	0.23	0.2	0.68
mgw-78	Megrim (*Lepidorhombus whiffiagonis*) in Divisions VIIb-k and VIIIa,b,d	wghmm	*	*	*	*	*	*	*	*	*	*	*	*
ang-78ab	Anglerfish (*Lophius piscatorius* and *L. budegassa*) in Divisions VIIb-k and VIIIa,b,d LOWER RANGE	wghmm	0.19	0.12	0.13	0.11	0.09	0.29	0.24	0.13	0.15	0.13	0.11	0.35
ang-78ab	Anglerfish (*Lophius piscatorius* and *L. budegassa*) in Divisions VIIb-k and VIIIa,b,d UPPER RANGE	wghmm	0.12	0.08	0.09	0.07	0.06	0.2	0.14	0.09	0.1	0.08	0.07	0.23
nep-25	Nephrops in North Galicia (FU 25)	wghmm	*	*	*	*	*	*	*	*	*	*	*	*
nep-31	Nephrops in the Cantabrian Sea (FU 31)	wghmm	*	*	*	*	*	*	*	*	*	*	*	*
nep-2627	Nephrops in West Galicia and North Portugal (FU 26-27)	wghmm	*	*	*	*	*	*	*	*	*	*	*	*
nep-2829	Nephrops in South-West and South Portugal (FU 28-29)	wghmm	*	*	*	*	*	*	*	*	*	*	*	*
nep-30	Nephrops in Gulf of Cadiz (FU 30)	wghmm	*	*	*	*	*	*	*	*	*	*	*	*
sol-8c9a	Sole in Divisions VIIIc and IXa	wghmm	0.36	0.2	0.21	0.18	0.15	0.48	0.5	0.24	0.27	0.23	0.19	0.67
ple-89a	Plaice in Subarea VIII and Division IXa	wghmm	0.39	0.22	0.23	0.19	0.17	0.51	0.56	0.26	0.3	0.25	0.21	0.74
pol-89a	Pollack in Subarea VIII and Division IXa	wghmm	0.24	0.15	0.16	0.13	0.11	0.35	0.32	0.17	0.19	0.16	0.13	0.45
whg-89a	Whiting in Subarea VIII and Division IXa	wghmm	0.3	0.17	0.18	0.16	0.13	0.41	0.41	0.21	0.23	0.19	0.16	0.55

4.2 Estimation of current exploitation (ToR b and c)

An example of what could be produced with the "Froese method", is shown for Anglerfish. The C-MSY projection model was applied to the landings data for anglerfish in ICES Divisions IIa & IIIa and Subareas IV, and VI. The model was tested using ranges of time series of data from 1973 to 2010 to evaluate the sensitivity of the model predictions for MSY to the assumptions used in the specification of the simulation.

The stock was considered to have low resilience in each projection. Figures 4.2.1 – 4.2.4 present the projections for the default run with reduced time periods. As would be expected, with no information other than the catch data time series the projection model results for MSY are highly dependent of the time series of catch entered. In each simulation the values of r and K are highly correlated with r predominantly at its lowest bound and k the upper bound. The projected MSY falls within the range of the input catches in each case and is totally dependent on the catch level, as would be expected from a un-calibrated equilibrium fit of the production model. There is no information on the MSY level based on the default settings and catch data alone.

Three of the default settings were examined for the sensitivity of the projected MSY estimates for the anglerfish to the projection specification. The scaling of the initial year, an intermediate year and the final year stock biomass relative to carrying capacity K. The MSY resulting from each of the model projections is highly correlated with the specification of the scaling and without determination from external information the MSY for the stock cannot be determined as is usual for models fitted to catch data alone. Figures 4.2.5 – 4.2.8 present the projections for runs with the settings and full year range selected for Figure 4.2.1 but with initial biomass set at 0.1K, 0.25K, 0.5K (as Figure 1) and 0.75K. The sensitivity of the MSY projections to the assumption of initial biomass is clear.

The determination of MSY from the forward projection equilibrium based model is extremely sensitive to the range of data available and the opinion / perception of the user with regard to the starting state of the stock. This must be determined outside of the model using external data as there is no information within the catch data to determine MSY uniquely.

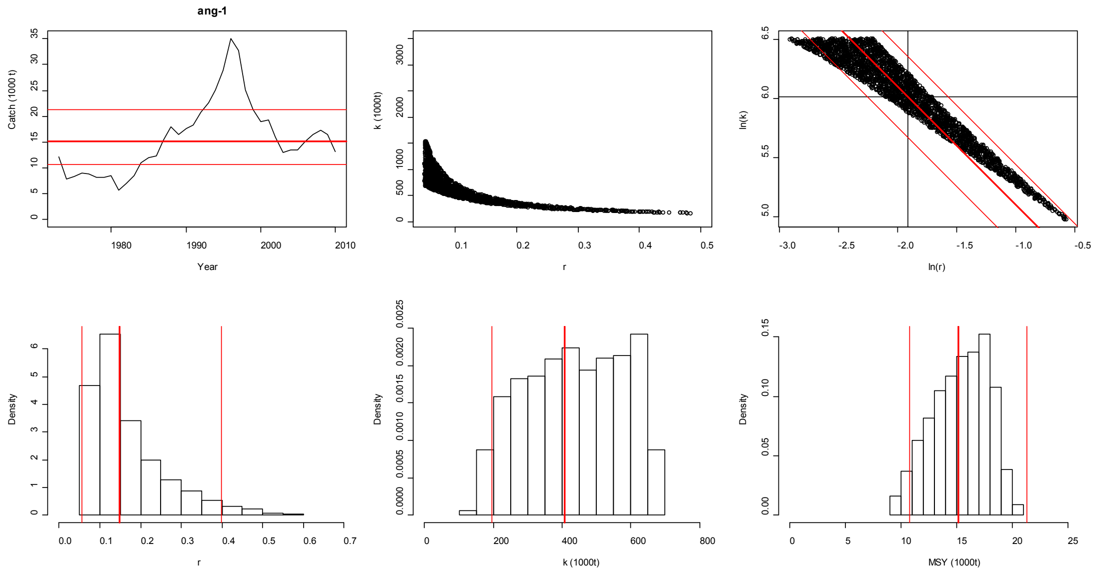

Figure 4.2.1. Anglerfish IV and VI C-MSY fitted to the full time series of landings data from 1973 – 2010.

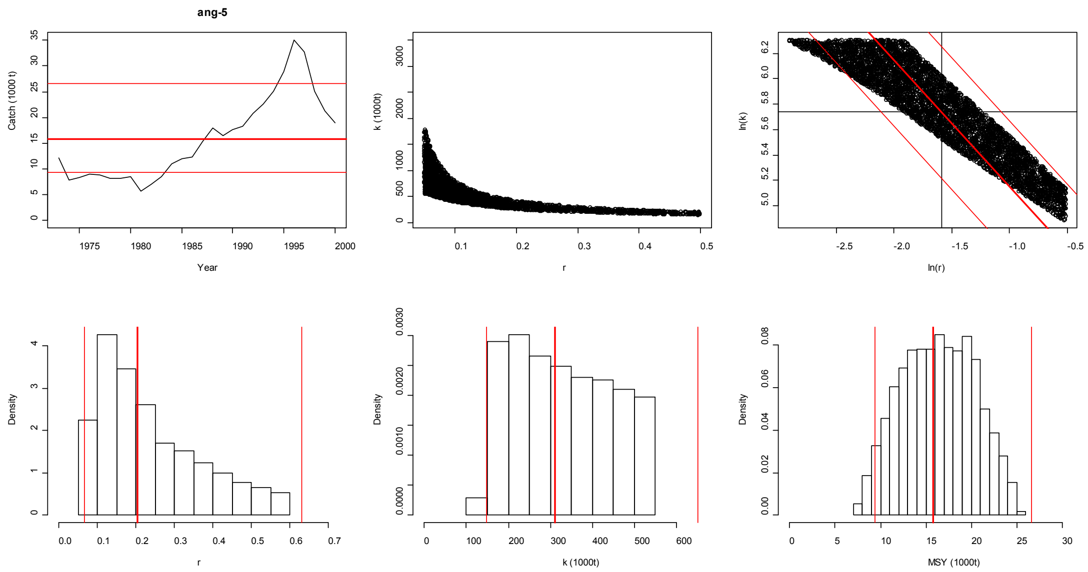

Figure 4.2.2. Anglerfish IV and VI. C-MSY fitted to the landings data from 1973 –1995.

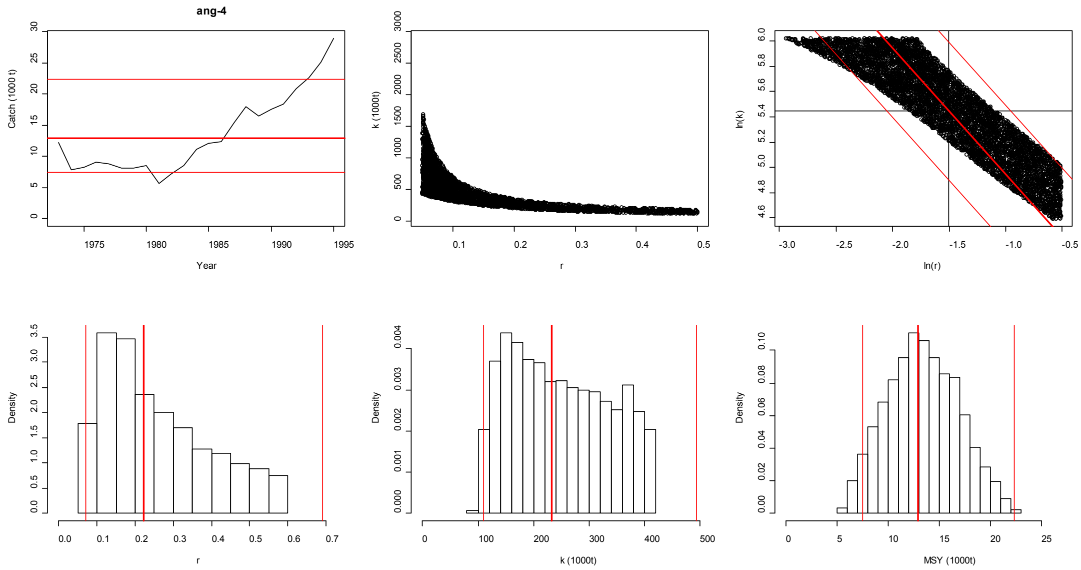

Figure 4.2.3. Anglerfish IV and VI. C-MSY fitted to the landings data from 1973 –1995.

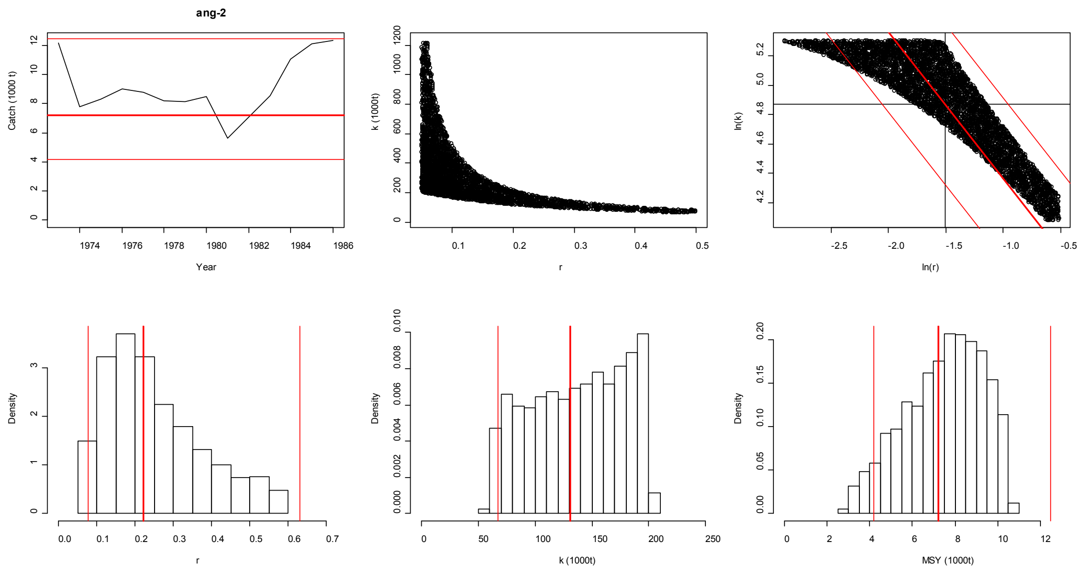

Figure 4.2.4. Anglerfish IV and VI C-MSY fitted to landings data from 1973 – 1986.

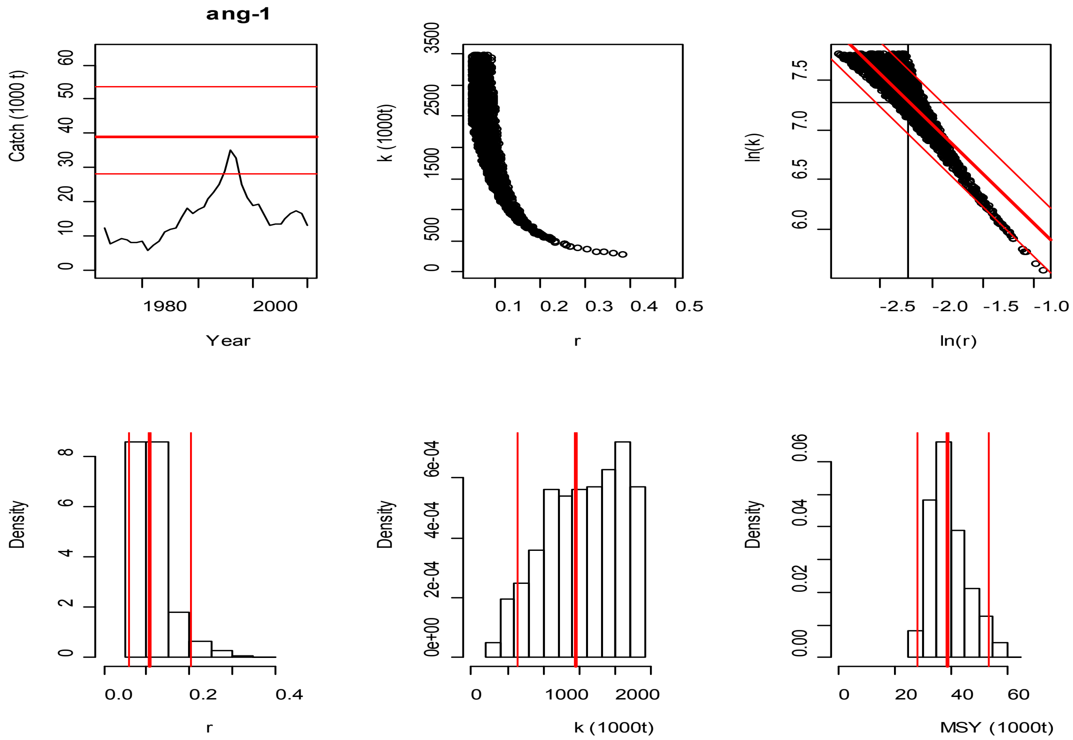

Figure 4.2.5. Anglerfish IV and VI C-MSY fitted to landings data from 1973 – 2010. Starting biomass 0.1K, year 1974 biomass in the range [0 – K], final year biomass [0 – 0.6K].

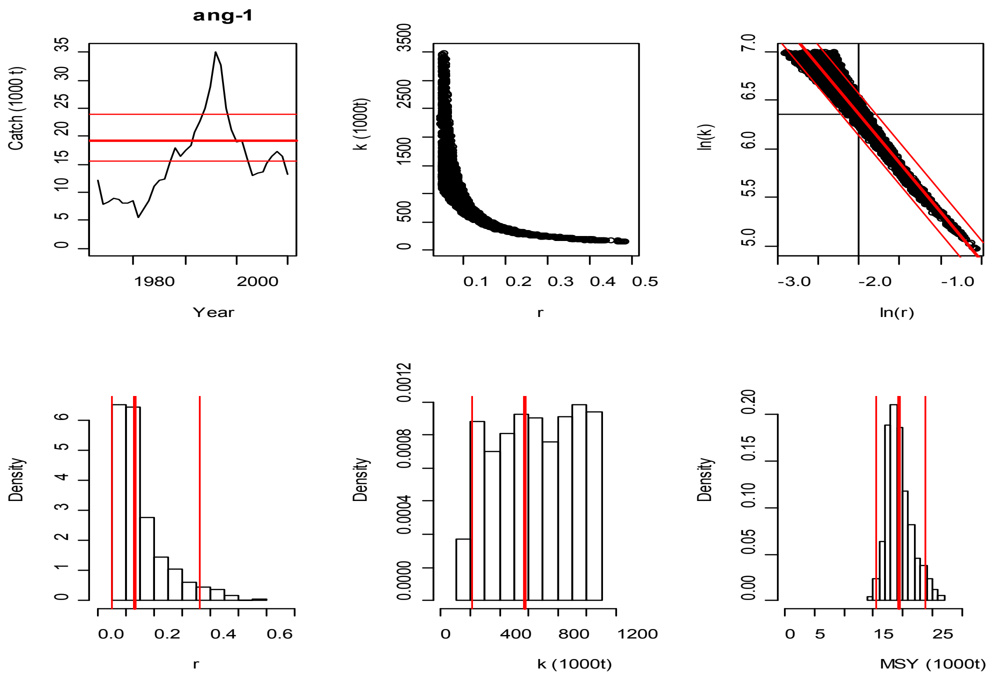

Figure 4.2.6. Anglerfish IV and VI C-MSY fitted to landings data from 1973 – 2010. Starting biomass 0.25K, year 1974 biomass in the range [0 – K], final year biomass [0 – 0.6K].

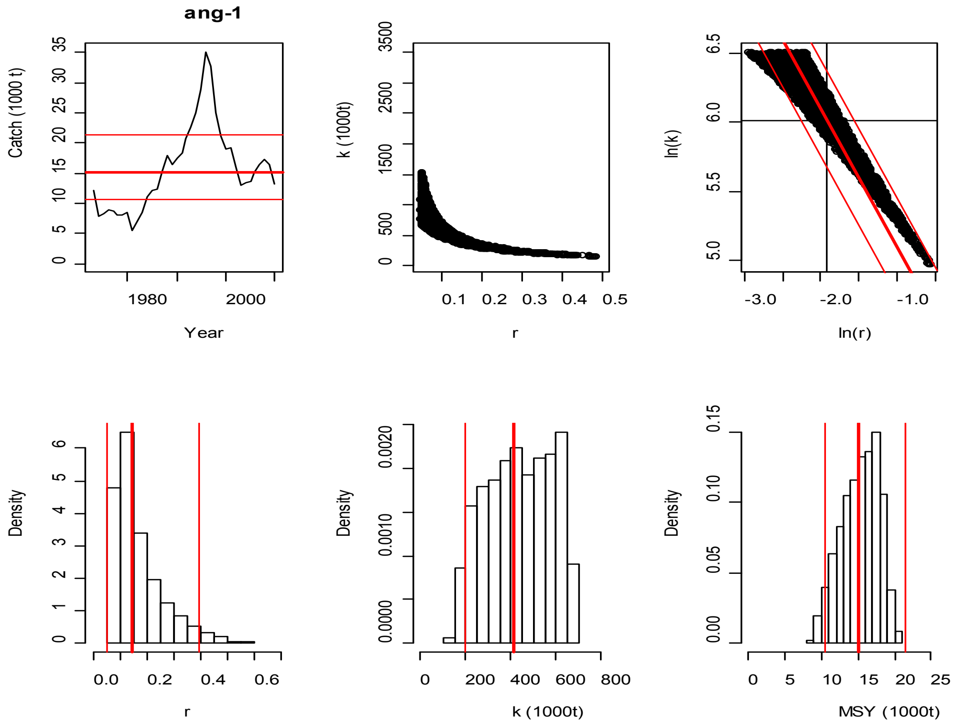

Figure 4.2.7. Anglerfish IV and VI C-MSY fitted to landings data from 1973 – 2010. Starting biomass 0.5K, year 1974 biomass in the range [0 – K], final year biomass [0 – 0.6K].

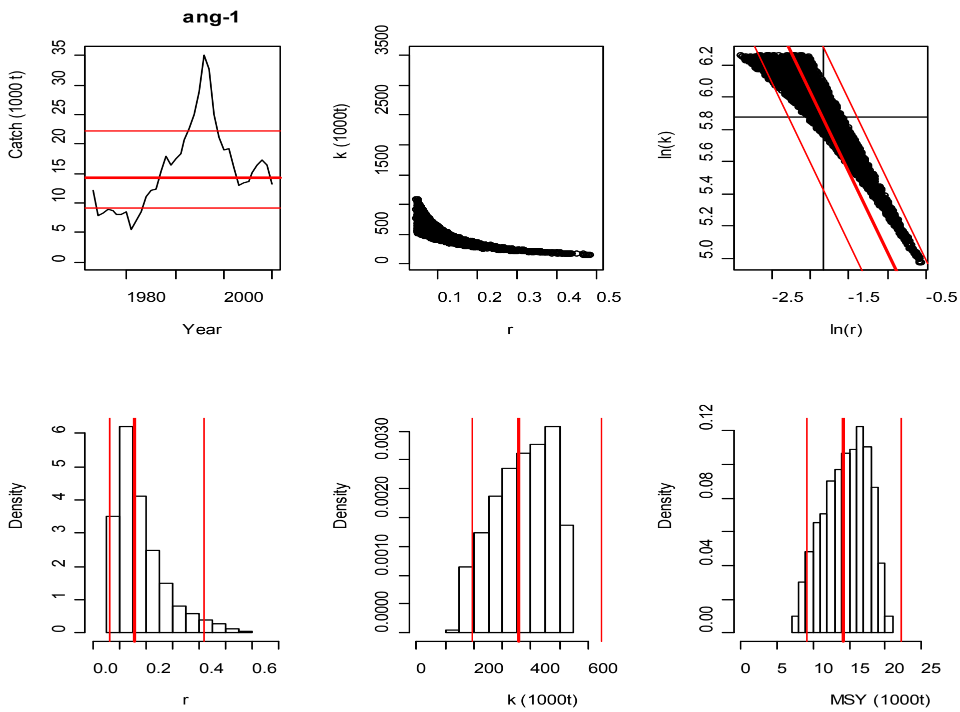

Figure 4.2.8. Anglerfish IV and VI C-MSY fitted to landings data from 1973 – 2010. Starting biomass 0.75K, year 1974 biomass in the range [0 – K], final year biomass [0 – 0.6K].

For the remaining 21 stocks where there is catch data and some index of abundance, there are a variety of approaches which could be used to generate an advice. Here the issue is how to produce a catch advice given that there is a valid assessment at least in relative terms. Currently advice for these stocks is on an empirical basis, but there are a range of assessment outputs for these stocks in the EG's ranging from proxies for F_{msy} and Z estimates, to forecasted population estimates. Based on the classification of the types of outputs available from these analyses by the EG's, a series of specifications for simulating HCR's (which could be applied to the assessment outputs) is given in Section 6.

5 Sub-group III: NWWG, AFWG, WGPAND, HAWG, WGWIDE, WGHANSA, WGBFAS and WGBAST stocks

5.1 Proxies for F_{MSY} based on life-history traits (ToR a and d)

A very crude attempt was made at estimating the fishing mortality reference points based on life history parameters using (Le Quesne and Jennings 2012). The estimations were based on L_{inf} or L_{max} only assuming knife-edge recruitment at age 1. This latter is most likely a wrong assumption for many of the stocks and hence a tabulation of the calculation are not shown here. The approach is considered scientifically sound and of potential use for data poor stocks in a mixed fisheries context. However, before the approach is applied a compilation of the needed life history parameters by ICES' expert groups is required. Making available computer code for the expert groups would facilitate the progress.

5.2 Estimation of current exploitation (ToR b and c)

5.2.1 Cod in Va

Although the Cod in Va is by some considered to be a data rich stock the simple method for estimating MSY from catch and resilience (WD1) was attempted for demonstration purpose. The plausible ranges for r were limited to 0.2-1.0, it was assumed that the biomass in the first data year (1955) was at 0.5K and that the biomass in the terminal year (2011) was 0.01-0.6. No assumption was made with regards to biomass relative to K the intermediate years. The estimated MSY was within a relatively narrow range of 377-398 kt (Figure 5.2.1.1), the parametric values being given in Table 5.2.1.1.

Figure 5.2.1.1

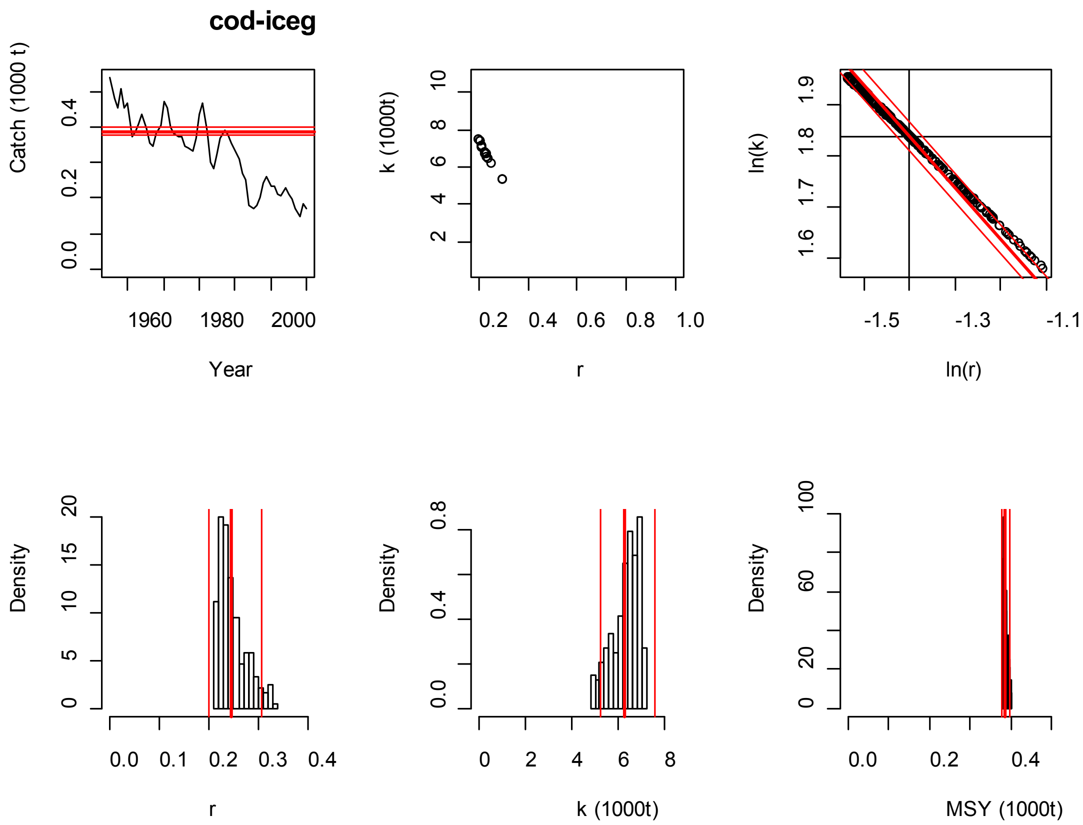

Figure 5.2.1.1

rmax	0.247
rmax - 2 SD	0.199
rmax + 2 SD	0.306
k	6,276
k - 2 SD	5,203
k + 2 SD	7,572
MSY	387
MSY - 2 SD	377
MSY + 2 SD	398

Table 5.2.1.1.

Given the best estimates of r (0.25) and K (6300 kt) from this model the most likely stock trajectories are that fishing mortality was high and increasing during the period 1955 to around 1990 but have since been declining and in the terminal part of the time series around half of the Fmsy (Figure 5.2.1.2). The biomass reached a minimum (below half the Bmsy) in early nineties but has increased since then and is estimated to be at Bmsy in the terminal year.

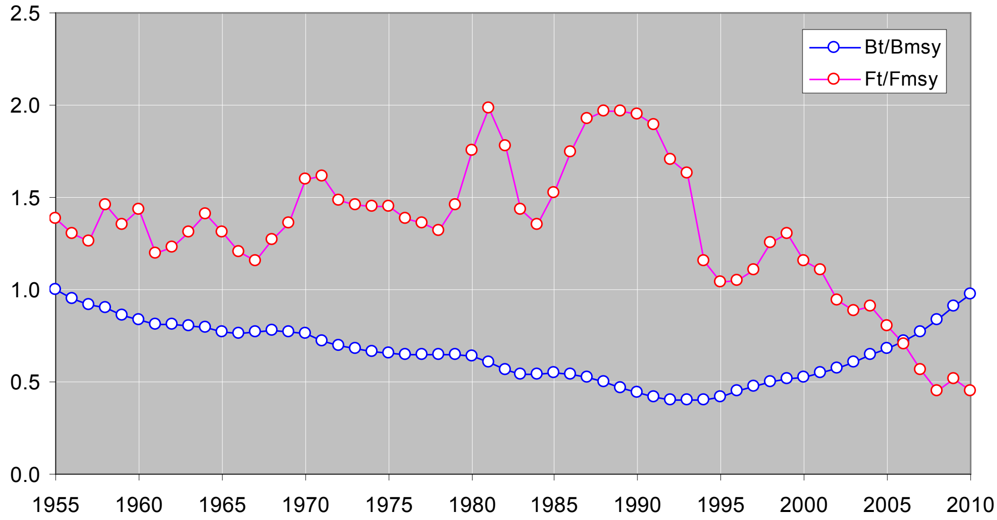

Figure 5.2.1.2

During the meeting a proposal was made to apply an MSY harvest control rule for a data-poor stock of the form described in WD1. A much-discussed example was the data-rich Icelandic cod stock (*Gadus morhua*, cod-iceg). Using the default assumptions of 0.5 k biomass at the beginning and 0.1 – 0.6 k at the end of the time series of catches resulted in a preliminary estimate of MSY = 387 (377 – 398, in 1000 t), consistent with previous estimates (Froese & Proelss 2010) based on yield-per-recruit analysis (346,852 with 95% CL 309,153 – 389,149) and on a Schaefer model with biomass data (347,718 with 95% CL 285,072 – 424,135). However, with a prior range of r = 0.2 – 1, the geometric mean of r = 0.247 (0.199 – 0.306) from viable r-k pairs underestimated the productivity of the stock, which the respective working group had set at F_{msy} = 0.2, i.e. with r ~ 0.4. This underestimation of r by the geometric mean from viable r-k pairs is a known bias of the Catch-MSY method, which was repeatedly stressed at the workshop. It indicates a need to identify other methods for selecting appropriate and representative r-k pairs. For example, assuming $r = 2\ F_{msy}$, the approximations of Gulland (1971) of $F_{msy} \sim M$ and Walters and Martell (2004) of $F_{msy} \sim 0.8\ M$ can be used to get $r = 2\ M$ or $r = 1.6\ M$, respectively. Corresponding values of k in the context of a Schaefer model can then be obtained from $k = 4 * MSY / r$.

One of the relative catch over relative biomass series that allow the Icelandic cod stock to survive with above inputs and outputs is shown in Figure 5.2.1.3. At the workshop, it was criticized that this series did not end up with the same biomass as obtained from equilibrium assumptions and the last catch/MSY in the time series (blue circle).

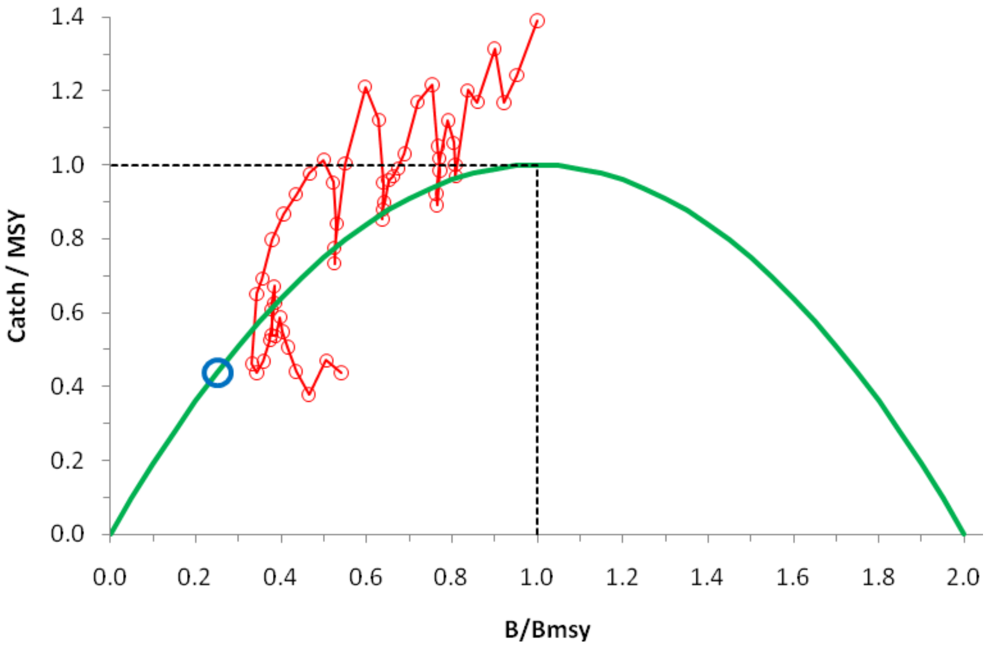

Figure 5.2.1.3. Reconstructed relative catch and biomass values, using the historical catches from 1955 to 2010, *MSY* = 387, *r* = 0.247, *k* = 6273, and starting biomass at k/2, with catches and biomass in 1000 tonnes. The blue circle indicates the equilibrium biomass 0.25 resulting from a relative catch of 0.44 in the final year.

Note that, in general, trying to reconstruct a supposedly realistic time series of biomass based only on an approximated or best-guess starting biomass, *r-k*, and catches, is not a meaningful exercise. Very small changes in starting biomass or *r-k* accumulate over the years and result in very large changes in biomass in the final years. For example, using the same *MSY* but *r* = 0.248 (instead of 0.247) with corresponding *k* = 6,242 (instead of 6,267) results in another viable series that ends very close to the blue circle (Figure 5.2.1.4), but this *r* still underestimates the *r* ~ 0.4 assumed by the working group for this stock. In other words, selecting an *r-k* pair that results in a final biomass near the equilibrium parabola does not result in an *r-k* pair that is significantly different from the initial one which was derived as geometric mean from the viable *r-k* pairs.

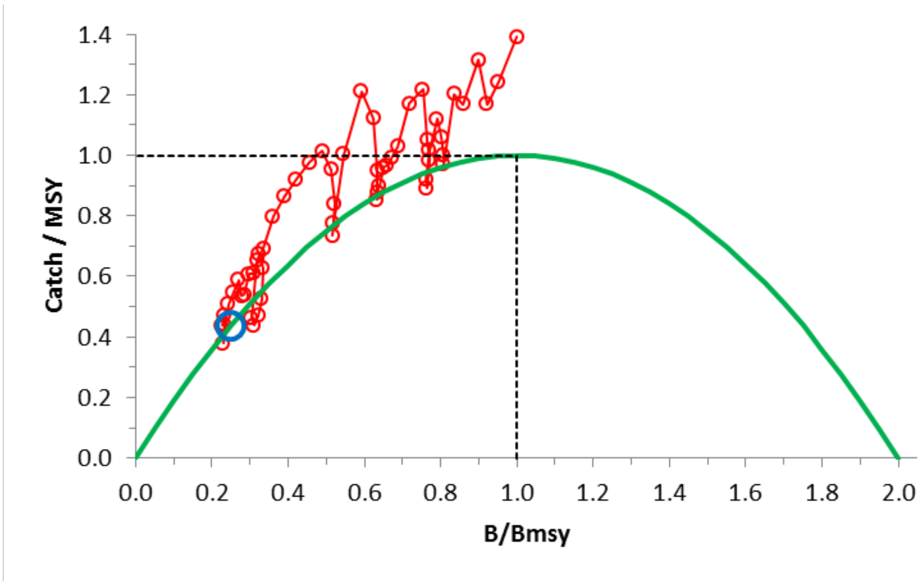

Figure 5.2.1.4. Presentation of another viable relative catch over relative biomass series, with same *MSY* and starting biomass as in Figure 5.2.1.3, but slightly modified values of $r = 0.248$ and $k = 6{,}242$. This series remains closer to the Schaefer equilibrium curve, but its *r* and *k* values are not significantly different from Figure 5.2.1.3.

It was also pointed out that the Catch-MSY method is sensitive to the depletion estimate, especially the relative biomass estimate at the beginning of the time series, and that methods were needed to improve estimation of that input value. For example, using $r \sim 0.4$ from the Icelandic cod working group and $MSY = 387$ from the first run of the Catch-MSY method does not result in a viable biomass series with the given catch data. However, changing the initial biomass from 0.5 *k* to 0.5926 *k* gives a viable series. Re-running the Catch-MSY analysis with 0.6 as starting biomass gives geometric mean $MSY = 363$ instead of the initial 387. A corresponding new *k* would be 3,630. Applying this *k* to the total biomass of Icelandic cod at the start of the time series in 1955 gives 0.65 *k*, i.e., 0.6 is indeed a more realistic value than the initial 0.5 *k*. Obviously, this is just one example and more work is needed to find out whether such iterative approach can be used to improve the estimate of initial biomass.

5.2.1.1 Exploring harvest control rules

As was stressed repeatedly at the workshop, initial comparisons with a variety of stocks suggest that the catch MSY-method provides very reasonable estimates of *MSY* given reasonable input data. However, its estimates of *r* (and *k*) strongly depend on the prior range of *r*, especially the lower prior limit of *r*. The method is not suitable for estimating realistic time series of biomass or the biomass in the final year. Additional information is needed to derive a recent biomass estimate from, e.g. the mean catch relative to *MSY* over the last years. For example, a Schaefer production model will suggest the equilibrium biomass B/B_{msy} that will eventually result from a constant relative catch Y/MSY as

$$\frac{B}{B_{msy}} = 1 \pm \sqrt{1 - \frac{Y}{MSY}}$$

Additional evidence is needed to decide whether the biomass is above or below B_{msy}.

Text book harvest control rules (Walters and Martell 2004, p. 47) such as tested and parameterized by Froese *et al*. (2011) for Europe, can then be used to set TACs for subsequent years. The parabolas in the Figures in this Section are calculated from the Schaefer equation with surplus production *Y* expressed relative to *MSY*.

$$\frac{Y}{MSY} = 2\frac{B}{B_{msy}} - (\frac{B}{B_{msy}})^2$$

The label on the vertical axis is expressed as Catches/*MSY* (rather than *Y*/*MSY*), because here we are interested in long-term projections such as what biomass will eventually result from a certain continuous catch, or what long-term catch is compatible with a certain biomass.

A possible application of that harvest-control rule for the Blue ling is shown in Figure 5.2.1.1.1. The Catch-*MSY* method estimated *MSY* = 11,649 t and the catch in the last year was 4550 t, equivalent to 0.39 *MSY*. *B* is considered below B_{msy} therefore in Figure 4, the Catch/*MSY* was set to the left side of the graph were $B/B_{MSY} < 1$. However the Catch-MSY method does not estimate *B* (current biomass). The *B*=0.22 B_{msy} in Figure 5.2.1.1.1 only derives from the equilibrium assumption where a sustained catch of 0.39 *MSY* will eventually result in a biomass of *B* = 0.22 B_{msy}. The actual current position of the blue ling stock on the plot can be anywhere on the line Catch/*MSY* = 0.39, either to the left (*Bcurrent* < 0.22 *Bmsy*) or the right (*Bcurrent* > 0.22 *Bmsy*) of the starting equilibrium point depicted in Figure 5.2.1.1.1.

An alternative harvest control rule that avoids zero catches was also presented at the workshop and is shown in Figure 5.2.1.1.2. The speed of recovery depends on the assumed productivity (the *r*-*k* pair) and how far the catches are reduced, i.e., their vertical distance from the green line. In this example, the HCR of Froese *et al*. (2011) in Figure 5.2.1.1.1 would rebuild the stock to B_{msy} in 14 years. With the alternative HCR in Figure 5.2.1.1.2, recovery would take 20 years.

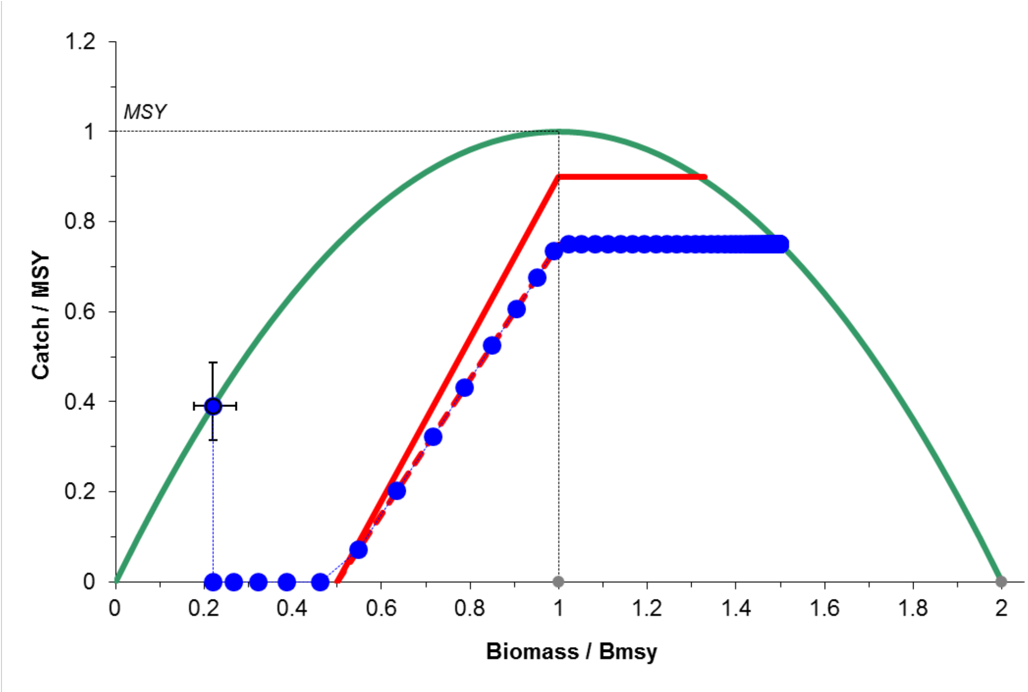

Figure 5.2.1.1.1. Precautionary harvest control rule for the Blue ling, based on the starting point of 0.39 Catch/MSY and 0.22 B/B_{msy}. The fishery would be closed until 0.5 B_{msy} is reached, then catches would increase linearly with biomass until 0.75 *MSY* is reached, and would then remain at that level for this low-resilience species. Such exploitation would eventually result in a biomass near 1.5 B_{msy} . The blue dots indicate years. With the assumed productivity, it would take 14 years to reach B_{msy}.

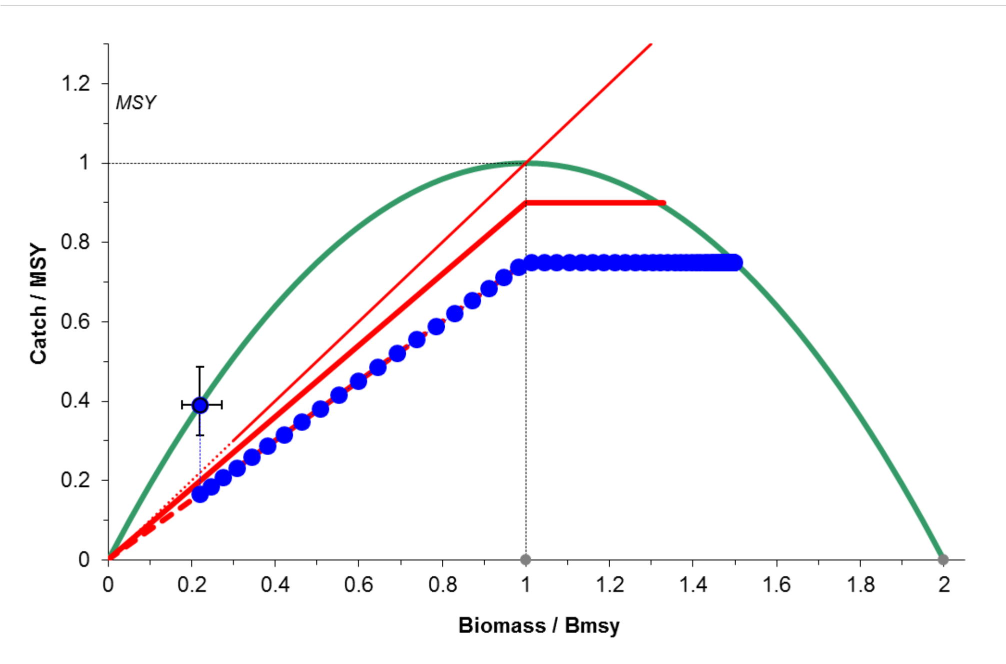

Figure 5.2.1.1.2. An alternative harvest-control rule that avoids zero catches. Note that with the same assumptions about productivity as in Figure 5.2.1.1.1, this approach takes 20 years to reach B_{msy}. The thin upper red line is the current HCR proposed by ICES, when expressed in catch/*MSY*.

Other evidence such as increase in catch per unit effort and increase in mean length in the catch would be needed to assure that the stock is indeed rebuilding as predicted by the average productivity assumed by the harvest control rules. Also, new, simple methods are needed to determine whether a stock is still (somewhere) above B_{msy}.

The thin upper red line in Figure 5.2.1.1.2 is the actual harvest control rule currently proposed by ICES, here expressed with catch/*MSY* rather than F/F_{msy} on the vertical axis. It has no precautionary distance to *MSY* and catches may actually exceed *MSY* if biomass exceeds B_{msy}. In its dotted lower part, *F* will decrease linearly with biomass, which has only a minor effect on the allowed catches. The application of the ICES HCR requires permanent detailed prediction of next year's biomass, whereas the catch/*MSY* model only requires such predictions when the stock falls below B_{msy}, an event that is less likely once stocks have recovered to 1.3 or 1.5 B_{msy}, respectively, with catches below *MSY*. As long as it can be assumed with some confidence that the stock will be above B_{msy}, next year's catch would remain constant. Finally, the ICES HCR with its allowed catches exceeding *MSY* encourages the maintenance of overcapacity for capture and processing, rather than using exceptional recruitment events for buildup of extra biomass to buffer stock size in years with below average recruitment.

5.2.2 Offshore cod in NAFO 0 and 1 and ICES XIV

Recent analytical assessment of the offshore cod in Greenlandic waters is not available. Same methodological procedures were applied to this cod stock as was done for cod in Va (see section above). The plausible ranges for r were limited to 0.18-0.6. It was assumed that the biomass in the first data year (1924) was at 0.5K and that the biomass in the terminal year (2011) was 0.01-0.6. No assumption was made with regards to biomass relative to K the intermediate years. The estimated MSY was within a relatively narrow range of 166-185 kt (Figure 5.2.2.1), the parametric values being given below:

rmax	0.18
rmax - 2 SD	0.142
rmax + 2 SD	0.227
k	4,115,055
k - 2 SD	3,624,957
k + 2 SD	4,671,415
MSY	184,755
MSY - 2 SD	165,756
MSY + 2 SD	205,932

The principal results are summarized in Figures 5.2.2.1, 5.2.2.2 and 5.2.2.3. According to the historical stock trajectory the fishing mortality was very high between 1960 and early 1990 and the stock more or less collapsed in the beginning of the 1970s. Very low fishing mortality since the early 1990's has resulted in a gradual increase in biomass, with the current biomass being estimated to be above Bmsy. The proposed advisory rule, where the current stock size is a function of the recent catches implies that the stock is only 1% of Bmsy. The catch (advice) trajectory following this rule would imply a closure of the fishery for the next decades. If however the current stock estimates are used this would imply that catches in the future years should be constrained to 0.9MSY (166 kt).

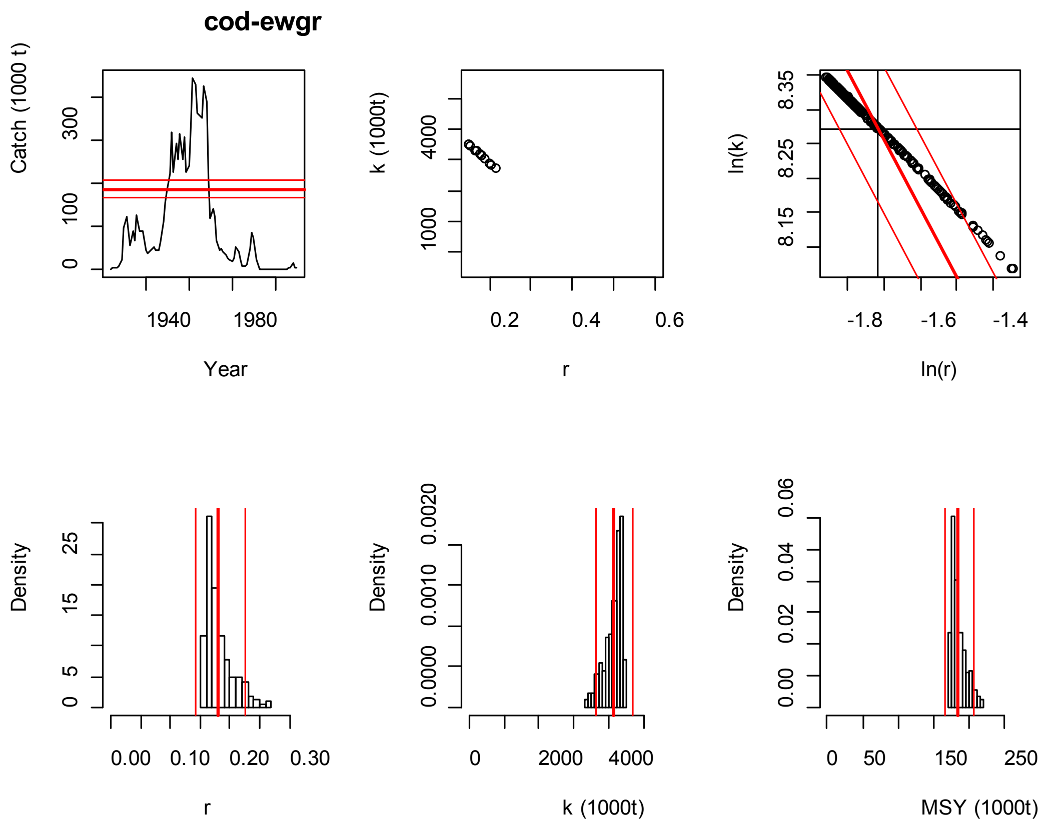

Figure 5.2.2.1

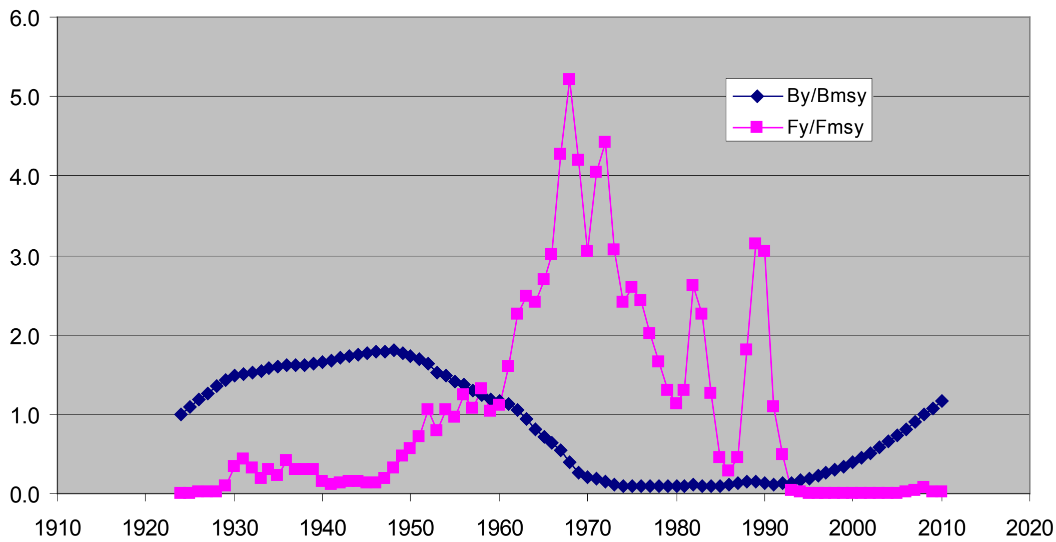

Figure 5.2.2.2

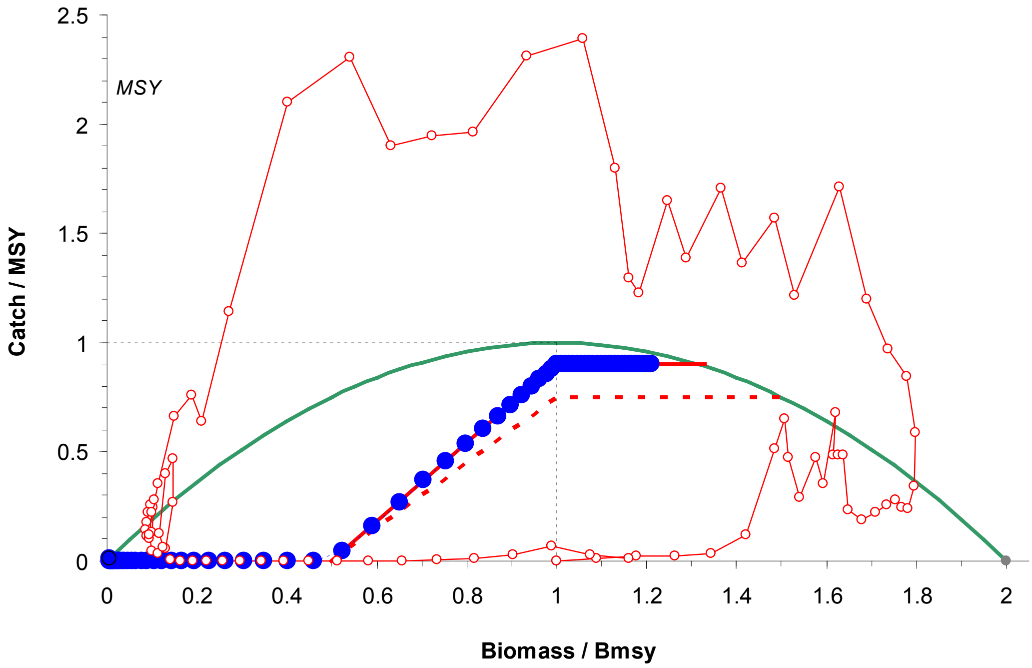

Figure 5.2.2.3

5.2.3 Irish Sea herring (Div. VIIa North)

The C-MSY method (Martell and Froese, submitted) was applied with the catch data available from the ICES HAWG 2011 report, with total catches covering the period 1987-2010. The options taken were as follows:

- the resilience of the stock was classified as "Medium", therefore having 0.2 and 1 as boundaries for the r parameter;

- the assumed biomass at the start of the time series, as a fraction of the parameter k, was 0.5;

- the final biomass boundaries, as a fraction of k, were 0.01 and 0.6.

The method application yielded 766 possible combinations of r and k. The estimated initial MSY was 4880 t, while in the end the geometric mean of MSY was 4940 t and MSY +/- 2 SD varied between 4460 t and 5460 t. The initial r parameter was 0.271, while after the model run the new upper bound for r was estimated as 0.88 and the geometric mean was 0.318. For the parameter k, the range was estimated to be between 27400 t and 78800 t, with a geometric mean of 62100 t. The main results from this application of the method to the Irish Sea herring are plotted in Figure 5.2.3.1.

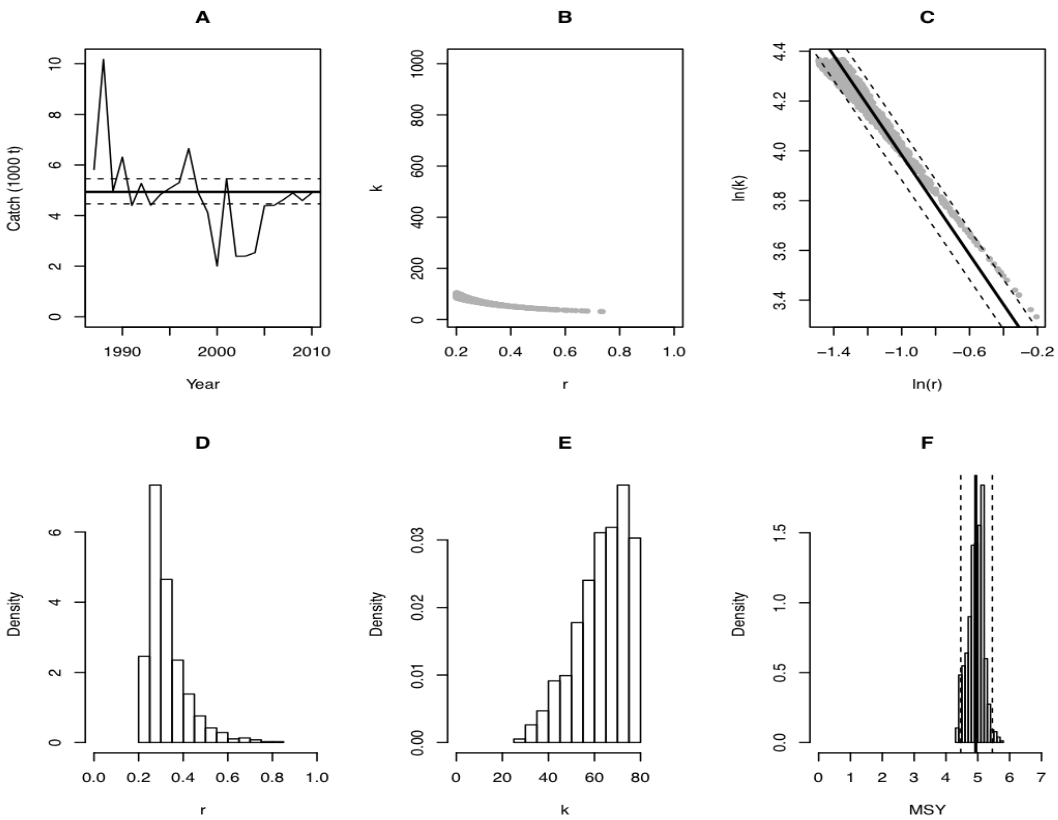

Figure 5.3.2.1 - Results of the C-MSY approach applied to Irish Sea herring (Div. VIIa North). Panel A: input catches, with estimated MSY and confidence interval; Panel B: pairs of r and k estimates selected by the method; Panel C: pairs of r and k in log scale; Panel D: density distribution of parameter r; Panel E: density distribution of parameter k; Panel F: density distribution of MSY.

The estimated MSY corresponds roughly to the average of the observed catches, indicating that, at present, the stock is being exploited at MSY. This is in agreement with the ICES advice (summarized in Figure 5.2.3.2) that states:

> "The catches have been close to TAC levels and the main fishing activity has not varied considerably. The 2010 acoustic survey estimates suggest that SSB is at its highest abundance in the 18 year time-series. Recruitment in recent years has been stable close to average recruitment in the time series. Increasing SSB and stable catches suggests decreasing exploitation",

concluding that catches should not be allowed to increase.

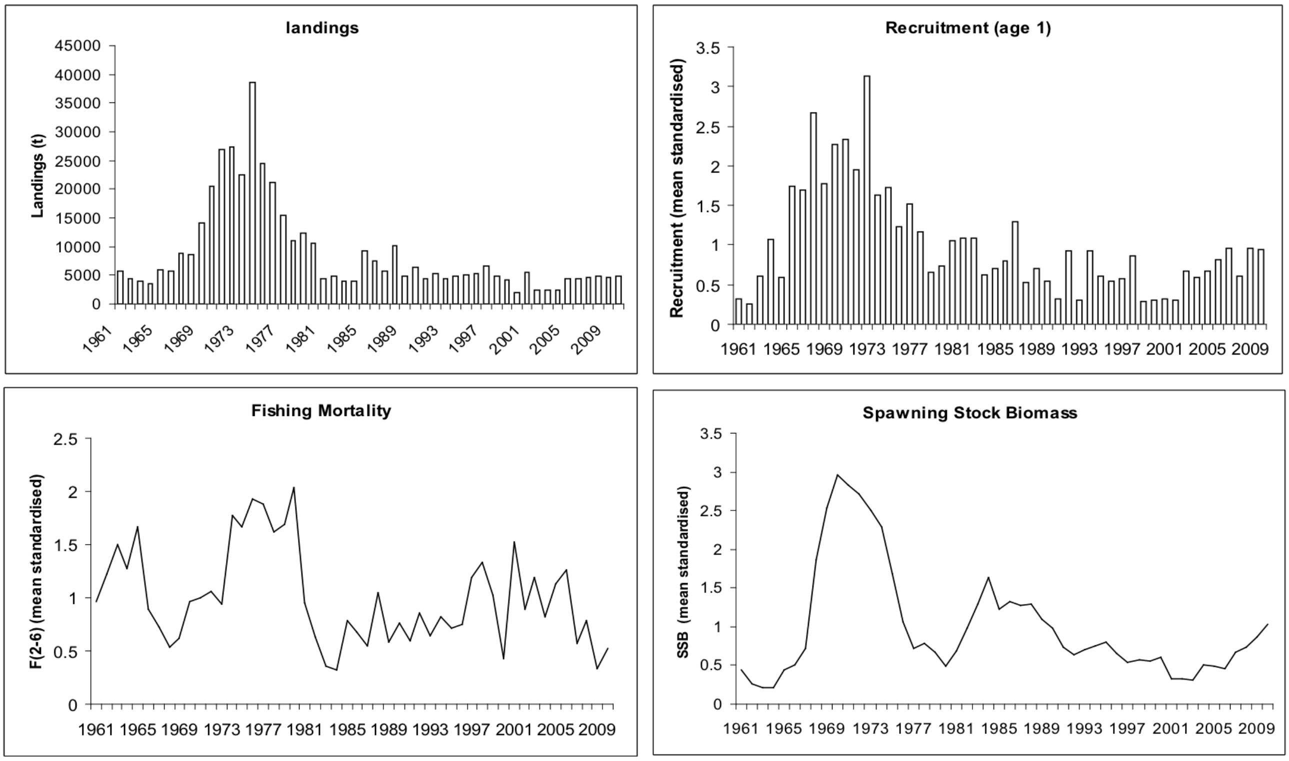

Figure 5.2.3.2 - Summary of the analytical assessment performed by the Herring Assessment WG in 2011.

However, the available WG catch estimates only cover the period 1987-2010. This leaves out from the analysis the period from 1961 to 1986, in which catches several times higher had occurred. It is likely that the estimate of MSY obtained with the complete time series could be different from the one obtained here.

5.2.4 Baltic flounder (Div. III 22-32)

The Catch-MSY method (Martell & Froese, unpubl) was tested with Baltic (ICES SD 22-32) flounder *Platichthys flesus*, using ICES landing data for this stock from 1973-2010. The resilience of flounder to catches was assumed to be medium to high.

As required input data values for the simulations, the initial bounds for *r* were set from 0.3 to 1.2. The initial bounds for *k* were taken as the observed maximal landings, 19639 and 30 times the max catch, ie 589170. It was further assumed that the biomass to carrying capacity ratio (B/k) in the first year of the series was 0.4 , and the B/k ratio after the last catch was taken in the range between 0.4 to 0.6.

The method revealed an estimated MSY for Baltic flounder of 16,385 tonnes (geometric mean, range 14921 - 17993 tonnes) (Table 5.2.4.1, Figure 5.2.4.1). According to the latest ICES assessment (ICES, 2011), total landings in the Baltic amounted to 16.582 tonnes in 2010, thus being only slightly higher than the estimated MSY.

It should be noted that, while the methods delivers quite realistic values for MSY, the methods normally underestimates values for r and overestimates those for k.

Additionally it should be noted that discards of flounder in other fisheries, especially for cod, are not yet included in catches. There are investigations demonstrating high discard rates for flounder in the Baltic (Probst et al. 2011; ICES 2011b). However, nothing is known about survival rates of discarded flounder in the Baltic.

According to the working group report (WGBFAS, 2011), although Catch at age (CANUM) and mean weight at age in the catch (WECA) data were available on yearly basis from Poland, Sweden and Germany, the commercial catch data were not used for an assessment due to discarding and age reading problems, according to the statements of WKAFAB (Gårdmark et al., 2007).

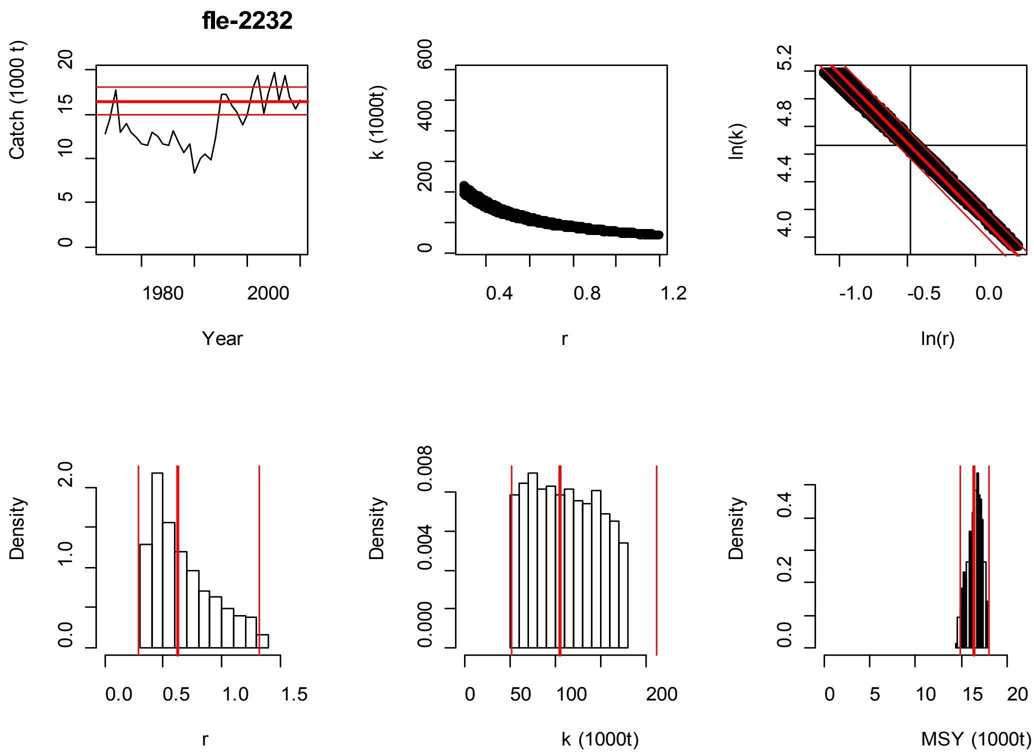

Figure 5.2.4.1: Results of MSY estimation from Catch-MSY method for Flounder in the Baltic (ICES SD 22-32)

Table 5.2.4.1: Outcomes of Catch-MSY method for Flounder in the Baltic (ICES SD 22-32)

Output from Catch-MSY analysis	
Last year with catch data	2010
Catch in last year	16582
rmax	0,623
rmax - 2 SD	0,293
rmax + 2 SD	1,32
k	105.133
k - 2 SD	52.326
k + 2 SD	211.233
MSY	16.385
MSY - 2 SD	14.921
MSY + 2 SD	17.993

5.3 Conclusions

Most of the stocks (redfish stocks) only have survey and catch statistics information that did not allow analytical assessments to be conducted due to lack of age information, short survey series or inappropriate survey design/coverage. Certain stocks such as cod in Greenland had sufficient aged based data but suffered from lack in time series or from changed biological regimes. A few stocks had potential for a full aged based assessment or have already been adopted for this in a benchmark procedure in 2012 (WKRED). Finally for a number of flatfish stocks in the Baltic that have not previously had requests for advice, have basic data for a full assessment but often suffers from short time series, thus assessment is possible dependent on available assessors.

5.4 Special request on cod in ICES Subarea XIV and NAFO Subarea 1

Greenland has requested ICES:

> *…to estimate or to provide guidelines for estimation of reference points for cod in ICES Subarea XIV and NAFO Subarea 1 (Greenlandic cod) including limit reference points or other estimates that are presently used to distinguish between a zero advice and an advice of reopening the fisheries.*

This request was added to the ToR for consideration at this ICES' WKLIFE meeting.

5.4.1 Initial response

WKLIFE did as for other stocks in its ToRs; namely, estimate proxies for MSY reference points by the use of life-history traits but considered the estimates as preliminary (see Section 5.2.2). Reference point estimation needs to be considered further by the ICES' NWWG at its April 2012 meeting when the ICES' stock experts will be in attendance and can make an informed decision.

The provision of biomass reference points that aim at guidance for closure/opening of a fishery at low stock size (<< Btrigger_msy) was not addressed by WKLIFE but was tabled at ICES' WKFRAME3 in January 2012. At WKLIFE, however, an attempt was made to apply HCR rules to the Greenland cod catch data in order to serve as potential reference points at low stock size. This requires further input from the ICES' stock experts at the forthcoming ICES' NWWG meeting.

6 Multi-annual harvest rules

The simulation framework used to evaluate the WKFRAME and ANNEX IV harvest control rules in WD2 Annex D (De Oliveira *et al.*) will be used to evaluate the utility of advice based on cases 3 – 5 as outlined below. Simulations will be based on the (two?) life-history characteristics of a cod (and herring?) like stock.

In categories 3 and 4 it is anticipated that annual catch advice will be provided based on the trend in the forecast from the assessment (Category 3) or the survey based rule (Category 4) with potential modification by a TAC constraint if required to stabilise the process and provide robust forecasts.

For category 5 it is considered that the process would provide multiannual catch advice. A TAC would be set on the basis of the reduction towards the F_{msy} target and then held constant for a period of years in order to measure a response to the change that was considered robust and not subject to noise in the estimation process. The suggested time for the setting of the constant catch is the time to reach maturity for the species

For each case the simulations to be examined for WKLIFE are outlined below.

6.1 Categories 3-5 simulation of WKFRAME3

6.1.1 Category 3 Full assessment and forecast trend

Data generated with noise added to catch and survey data in order to simulate process and measurement error.

A full assessment model fit and a forecast for two years ahead of the assessment year with results used at a relative scale as currently used in ICES ACOM advice.

Reference points determined from the fitted assessment and comparison on the relative scale between the assessment estimate of exploitation and the reference level.

A catch constraint applied to harvest rules that lead to 3, 5 and 10 year scheduled reductions in fishing mortality towards the Fmsy target.

6.1.2 Category 4 Survey data and catch curve analysis

The utility of simple HCR based on recent data from surveys or trends in survey time series will be explored in an extension of the simulations carried out for the WKFRAME rules. The addition of a catch curve analysis (see case 5) based on recent catch at age data to estimate changes towards the reference fishing mortality will also be explored.

Where the Fmsy proxy is based on growth characteristics (F0.1, Fmax) the survey data required is an index of the fishable biomass; where an Fmsy proxy is used the survey index should be derived for the spawning biomass estimates.

Two HCR were suggested for further exploration:

The Icelandic HCR

Catch =Fishing mortality x Biomass

C_{y+1}= min(1, SSB_y / $SSB_{trigger}$) Fmsyproxy FishableBiomass

C_{y+1} = min(1,$U^{SSB}{}_y$/$U_{trigger}$) Fmsyproxy $U^{FB}{}_y$

Note $U^{SSB}{}_y$ (spawning biomass) is not nessecarily the same as $U^{FB}{}_y$ (fishable biomass),

it is considered that Fproxy = C_y/$U^{FB}{}_y$ Fmsyproxy = C_{msy}/$U^{FB}{}_{msy}$

Greenland hailbut NAFO

TAC adjustments based on the perceived status of the stock from research surveys

$$TACy{+}1 = TACy\ \ (1+\lambda\ slope)$$

where *slope* = unweighted average slope of log-linear regression lines fit to the last five years of each index (mean weight per tow from surveys) and λ = an adjustment variable for the relative change in TAC to the perceived change in stock size.

6.1.3 Category 5 Catch curve analysis

ACOM has provided advice based on catch curve analysis for plaice in ICES Subareas VIIh-k on the basis of the ratio of a catch curve estimate of current fishing mortality to that of a catch curve estimate of F0.1 and Fmax derived from a short series of recent catch at age data. This approach to giving advice based on un-calibrated catch curve analysis requires evaluation.

The simulations used to evaluate Annex IV harvest control rules established that when pseudo cohort analysis is used management rules can be unstable. WKLIFE will use the simulation framework to examine whether providing relative management advice based on catch curves (as for the plaice in VIIh-k) is appropriate and whether this approach can be used for stocks for which there is only a limited number of years of age data. If appropriate the estimates from this method could be used to supplement the survey based approach suggested for category 4 stocks.

In cases where this rule is applied, maintaining the TAC for a period of time in order to determine the effects of the management action before making further changes avoids chasing noise. The period of time that will be evaluated initially will be the number of years to the age of 50% maturation.

6.2 Categories 6 and 7

6.2.1 Category 6

The empirical approach suggested by WKFRAME3 can lead to stock crash or fishery closure if applied on an annual basis without some stabilisation mechanism. The empirical rule is intended to be applied on a timescale relative to the generation time in the stock (e.g. time taken for individual to reach 50% maturity). However when catch adjustments are made only on a multiannual basis (as a means to change the exploitation), there is a trade off between taking sufficient action to adjust the exploitation towards what is sustainable and reacting to short term noise in the metrics. A method for dealing with this may be to introduce a tiered approach to any change limits based on expert judgement on the degree of overexploitation.

6.2.2 Category 7

In relation to WKLIFE, PSA (see Section 2.4) has the potential for use with the category 7 stocks where there is a need to examine the relative level of risk to stocks. These methods enable comparative assessment of risk, and therefore assessment of which stocks in a mixed catch should take priority for further assessment. The analysis would also give a relative assessment of their risk in relation to the assessed stocks. However, it would be important to include the effect of all fishing activities affecting the stocks.

PSA also gives an overview of the effect of fishing in relation to the life-history characteristics of the stocks affected. It is likely that certain stocks, such as the elasmobranches, would group together on a PSA plot and enable common approaches between stocks to be adopted. When interpreting these results it must be remembered that this is a semi-quantitative analysis of risk in order to decide on priorities, and not a stock assessment.

For the moment, this is the only approach that WKLIFE can propose for this category. However, it should not be forgotten that such an approach (PSA) will not provide reference points but can indicate high risk cases that require special attention (see Section 2.4).

7 Discussion and conclusions

WKLIFE has demonstrated that ICES should be endeavouring to move more stocks into the data-adequate category over time and further has provided a valuable insight into the challenge at hand and a way forward.

The findings of the workshop may be summarised as follows.

ToRs a) and d):

SPR and F_{SPR} reference points have been identified as proxies for SSB_{MSY} and F_{MSY} respectively. These reference points could be applied in relation to category 3, 4 and 5 stocks, and could be used to inform risk assessment approaches applied to category 6 and 7 stocks. These reference points can be calculated on the basis of life-history information and knowledge of selection patterns. Where life-history information is not known for a specific stock, invariant life-history relationships can be used to fill the data gaps based on limited observations of an individual stock's specific biology. However further work is required to understand the potential error associated with the use of reference points calculated in this manner. It is noted that these reference points are consistent with the requirements of criteria 3.1 and 3.2 of the MSFD Descriptor 3. None of the indicators proposed under criteria 3.3 were considered, though it is noted that stock based size metrics are related to the *catch curve* approaches discussed under ToR b).

Life-history traits (LHTs) should be compiled by stock experts in the relevant assessment working groups. LHTs are available from a number of sources including FishBase, literature not (yet) accounted in FishBase, grey literature, and recent estimates based on DCF data collection. WKLIFE compiled LHTs for a number of stocks in catch-MSY templates. In some cases, this implied assembling LHTs estimated from different methods, at different periods of time and using LHTs estimated in one stock for another one, i.e. assuming similar growth, maturity, mortality, steepness… for different populations. Stocks experts should review and advance further this work in order to use the most appropriate LHTs estimates and to document the rationales for using or rejecting LHTs. For example, the range of sampling for VBGF should be checked to use the parameters.

Specifically, with respect to ToR d) some data are not included in ICES' assessments and work is needed to investigate how to incorporate them, including by developing new models.

ToRs b) and c):

WKLIFE was designed to define reference points for stocks where only LHTs are available. The process of stock categorization revealed that for most stocks covered by each of the three sub-groups I, II and III that much more data are available. These included:

- DCF data, e.g. length and age structure for many stock;
- commercial CPUE trends;

- times-series of landings data, some of which may be long with good reliability. For example, deep-water species tend to be caught by target fisheries. On the one-hand large offshore trawlers have been reporting catch for long, i.e. starting well before EU-logbooks and landings have mainly gone through auction market so that track records may be more reliable than for some coastal species caught as bycatch in several fisheries. On the other hand, artisanal fisheries for deep-water species such as longlining for black-scabbardfish off Portugal and blackspot seabream in the Strait of Gibraltar, involved well identified fleets, landings into one or a few ports only. As a result, these stocks have rather long and reliable catch records appropriate for some modeling; e.g. DCAC.
- survey times-series are available for a number of by-catch species considered by subgroup 1 e.g. gurnards and flatfishes.

Two different issues are:

(1) The use of all available data by assessment expert groups. It appeared that in some cases available data are not used, which may have a number of reasons, e.g. insufficient human resources, knowledge of experts about data availability in other countries, agencies, etc…, delays between data collection and availability to, for example, ICES or web-based facilities.

(2) Some assessments are carried out by experts groups and not used for advice. These assessments may not be fully reliable, e.g. statistical properties not good, inconsistencies or may provide only parts of the desired information. However, there is probably more information available for advice than that currently used.

ToR e):

The work presented in WD2 uses the Management Strategy Evaluation (MSE) framework to evaluate the catch rule proposed by WKFRAME3 in terms of its ability to meet MSY objectives. The catch rule relies on the availability of a time-series of a survey biomass index, and combines three factors in order to provide TAC advice; namely, a survey biomass trend factor, a precautionary scale-down factor relating current biomass to a trigger level, and a factor relating current exploitation to MSY levels. The catch rule is intended to be used in circumstances where no analytical assessment exists, so scaling to true stock size becomes a problem, and the rule relies on proxies for current stock size and MSY levels. Although the preliminary study in WD2 does not help with the problems associated with estimating the three factors, in particular with scaling the biomass index and using suitable proxies, they do however explore the behaviour of the catch rule, both when the scaling and proxies are appropriate, and when they are not, and under scenarios representing a limited range of uncertainties.

The main conclusions are: unbiased estimates of MSY/B_{MSY} (the MSY rate), exploitation rate and survey catchability are needed in order to deliver MSY targets; where a time-lag in the factor relating current exploitation to MSY levels is unavoidable, a TAC constraint is needed to stabilise the catch rule and a substantially higher risk of unintended stock depletion to low levels is evident; when applying the precautionary scale-down factor, it is better to set the biomass trigger level too high than too low.

The simulation framework used to evaluate the WKFRAME3 and ANNEX IV harvest control rules presented and discussed in WKLIFE will be used to evaluate the utility of advice based on categories 3 – 5 as outlined in Section 6. The simulations will be undertaken after the WKLIFE meeting and the results presented to ACOM's ADG-INTRO in the first week of March 2012.

8 References

Throughout this report there have been a number of references cited within the Sections 2 to 6. In this Section 8, these references are collated.

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Annex A: Agenda

Daily schedule (except **13 Feb – Start at 09:30** & **17 Feb – End at 17:00**):

09:00	start
11:00	Coffee-break
13:00	Lunch
16:00	Coffee-break
18:00	end

Addressing ToRs:

13 Feb, 09:30 to 14 Feb, 11:00	a) Identify options for determining proxies for FMSY for stocks without quantitative forecasts, using life history traits and exploitation characteristics; b) Identify methods for estimating current exploitation based on available limited information (for instance catch and survey data);
14 Feb, 11:30 to 15 Feb, 11:00	c) Apply the above to the stocks in Table 1 and identify stocks for which this can be used and stocks for which there is insufficient information; d) Identify the data to be collected for the stocks in Table 1 in order to implement the approach under a) and b)
15 Feb, 11:30 to 16 Feb, 18:00	e) Identify options for multi-annual harvest rules for the stocks where there is sufficient information to apply the approach under a) and b)
17 Feb, 09:00 11:30-17:00	Report writing and collation Report discussion and adoption

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Annex C: Recommendations

Recommendation	For follow up by:
1. Section 2.1.1: Further work can be conducted to develop understanding of systematic relationships between SPR reference points, life-history and F_{MSY}, and to develop ICES' guidelines for setting SPR reference points.	WGMG
2. Section 2.1.1: F_{SPR} and SPR reference levels designated to maximise yield whilst maintaining reproductive output can be considered appropriate reference points for indicators applied under the MSFD Descriptor 3 for criterion 3.1 (Level of pressure of the fishing activity) and criterion 3.2 (Reproductive capacity of the stock) respectively.	ACOM SCICOM
3. Section 2.6.1: Categorization by stock and the rationale behind the classification to be reviewed by ICES' stock experts.	WGDEEP, WGEF and WGNEW
4. Section 2.6.2: Categorization by stock and the rationale behind the classification to be reviewed by ICES' stock experts.	WGNSSK, WGCSE, WGHMM and ICES Secretariat
5. Section 2.6.3: Categorization by stock and the rationale behind the classification to be reviewed by ICES' stock experts.	NWWG, AFWG, WGPAND, HAWG, WGWIDE, WGHANSA, WGBFAS, WGBAST and WGEEL
6. Section 7: Life-history traits (LHTs) should be compiled by ICES' stock experts in the relevant assessment working groups. LHTs are available from a number of sources including FishBase, literature not (yet) accounted in FishBase, grey literature, and recent estimates based on DCF data collection. Stocks experts should review and advance further this work in order to use the most appropriate LHTs estimates and to document the rationales for using or rejecting LHTs. Stocks experts should review and advance further the work of WKLIFE in order to use the most appropriate LHTs estimates and to document the rationales for using or rejecting LHTs.	WGDEEP, WGEF and WGNEW WGNSSK, WGCSE, WGHMM and ICES Secretariat NWWG, AFWG, WGPAND, HAWG, WGWIDE, WGHANSA, WGBFAS, WGBAST and WGEEL
7. Section 7: The simulation framework used to evaluate the WKFRAME3 and ANNEX IV harvest control rules presented in WKLIFE will be further evaluated after the WKLIFE meeting and the results presented to ACOM's ADGINTRO in the first week of March 2012.	ADGINTRO ACOM

Annex D: WKFRAME3 simulations (Working document WD2)

Evaluation of WKFRAME3 catch rule

José De Oliveira, Chris Darby, Carmen Fernández and Carl O'Brien
February 2012

Introduction:

Catch rule proposed by WKFRAME3 to give advice in year y for year y+1:

$$C_{y+1} = r\ b\ f\ C_{current} \quad 1$$

where

$C_{current}$ = is the catch, either in the most recent year or averaged over a number of recent years

r = trend in biomass (value >0)

b = proxy for current (stock size / $B_{MSY\text{-}trigger}$), but not greater than 1 (hence, value >0 and ≤1)

f = proxy for (F_{MSY} / current exploitation) (value >0)

We simplify this rule here to:

$$TAC_{y+1} = r\ b\ f\ TAC_y \quad 2$$

where TAC_y denotes TAC in year y. Using the TAC allows the HCR to be independent of realised catch, which may differ somewhat from the intended levels of catch (this mismatch being commonly treated as "implementation error", which although not considered here, could be investigate in future work).

For the purposes of this study, it has been assumed that no analytical assessment exists for the stock (and therefore no quantitative forecasts are conducted), but that a time series of an index of abundance I_y (here, assumed to be an age-aggregated survey total biomass index, or survey SSB index) is available to be used in the catch rule. The lack of an analytical assessment means that an estimate of the survey catchability coefficient q would not be available, potentially causing a problem for the application of the catch rule because of the relative scaling required for the calculation of b and f (e.g. to put "stock size" on the same scale as $B_{MSY\text{-}trigger}$, and "current exploitation" on the same scale as harvest rate F_{MSY}). For this study we assume that an estimate of q is available, but capture any issues related to scaling by considering alternative HCR options (the three options each for b and f mentioned below, but see also Table 1).

There are potentially a large number of options of what to use for the derivation of r, b and f. In order to keep the number of options covered at a manageable level, this study considers a single calculation for r, based on HCR 4 in De Oliveira et al. (2010), described in Appendix 1, and three options each for b and f. Combined with the number of operating model scenarios considered (as was done in De Oliveira et al. 2010, see Table 1 below), this gives a total of 72 comparisons per stockoid (codoid only is considered here). Although this sounds a rather large number, it is hoped the layout of the comparisons in the Appendices will make comparisons manageable.

Although this study will not help with the problems associated with estimating *b* and *f*, in particular associated with scaling the biomass index and using suitable proxies, it does explore the behaviour of the catch rule, both when the scaling and proxies are appropriate, and when they are not, and under scenarios representing a limited range of uncertainties.

Calculation of r

The calculation of *r* relies on the availability of a time series of survey total biomass index I_y, and is given in Appendix 1.

Calculation of b

The calculation of *b* is as follows:

$$b = \min\ [qI_{y-1}^{SSB}/B_{\mathrm{MSY-trigger}};\ 1] \tag{3}$$

In year *y*, it is possible that the SSB index value for that year, I_y^{SSB}, is already available when the advised catch for year *y*+1 is proposed. However, for consistency with the calculation of *f* (see equation 4 below), we propose using I_{y-1}^{SSB} for *b* as well. Three options are considered to represent $B_{\mathrm{MSY\text{-}trigger}}$, namely 0.5 B_{pa}, B_{pa} and 1.5 B_{pa}. These options should capture both the uncertainty about whether the appropriate level of $B_{\mathrm{MSY\text{-}trigger}}$ is being used, and scaling issues associated with the survey SSB index I_{y-1}^{SSB} (i.e. uncertainty about *q*).

Calculation of f

The calculation of *f* relies on an appropriate definition for "current exploitation". Recalling that *f* = proxy for (F_{MSY} / current exploitation), if the ratio $C_{y-1}/(qI_{y-1}^{SSB})$ is used to represent current exploitation (where year *y*-1 is used given that catch in year *y* will not yet be available in year *y*), then the numerator for *f* should be expressed in the same terms (i.e. as a harvest rate). Therefore, F_{MSY} should be replaced by the MSY harvest rate: $MSYR = MSY/B_{\mathrm{MSY}}$. The calculation of *f* is therefore as follows:

$$f = X_{\mathrm{MSY}}/[C_{y-1}/(qI_{y-1}^{SSB})] \tag{4}$$

where X_{MSY} represents an estimate of *MSYR*. As before, in order to capture both the uncertainty about whether an appropriate estimate of *MSYR* is being used, and scaling issues associated with the survey SSB index I_{y-1}^{SSB} (i.e. uncertainty about *q*), three options for X_{MSY} are considered, namely 1.5 *MSYR*, *MSYR* and 0.5 *MSYR*, where *MSYR* is the "true" MSY harvest rate value from the operating model.

Application of a TAC constraint

The combination of the three factors *r*, *f* and *b* could lead to TACs that fluctuate markedly from year to year, and a TAC constraint can be used to guard against such fluctuations:

$$(1-\delta)TAC_y \leq TAC_{y+1} \leq (1+\delta)TAC_y \tag{5}$$

In this study, δ= 0.2.

Operating models:

The operating models are based on those developed at the June 2008 STECF meeting (see STECF 2008, De Oliveira et al. 2010), and are given in Table 1, along with the HCRs considered. The simulated populations were generated based upon cod.

Two initial states are considered: well-managed (harvest rate $F \sim F_{MSY}$, and spawning stock biomass $SSB \sim B_{MSY}$) and overfished ($F > F_{MSY}$ and $SSB < B_{MSY}$).

Table 1. Operating Model and HCR scenarios. F_{MSY}, the harvest rate that should give rise to the MSY when the stock is at B_{MSY}, the spawning stock biomass (SSB) that produces the MSY. The cod-like Operating Model assumes a Ricker stock-recruit relationship. Each scenario is composed of the productivity (steepness of the stock-recruitment relationship), the initial status, and the error model. Nine HCR variants are considered.

Scenario	Factor	Level
cod	Stock	Cod like
stk0.9	Stock Recruitment	High production - Steepness = 0.9
stk0.75		Lower production - Steepness = 0.75
stk#.stat1	Initial status	Well managed, i.e. $F \sim F_{MSY}$ and $SSB \sim B_{MSY}$
stk#.stat2		Overfished, i.e. $F > F_{MSY}$ and $SSB < B_{MSY}$
stk#.#.hcr1	HCR	$B_{MSY\text{-trigger}} = 0.5\ B_{pa}$; $X_{MSY} = 1.5\ MSYR$
stk#.#.hcr2		$B_{MSY\text{-trigger}} = 0.5\ B_{pa}$; $X_{MSY} = MSYR$
stk#.#.hcr3		$B_{MSY\text{-trigger}} = 0.5\ B_{pa}$; $X_{MSY} = 0.5\ MSYR$
stk#.#.hcr4		$B_{MSY\text{-trigger}} = B_{pa}$; $X_{MSY} = 1.5\ MSYR$
stk#.#.hcr5		$B_{MSY\text{-trigger}} = B_{pa}$; $X_{MSY} = MSYR$
stk#.#.hcr6		$B_{MSY\text{-trigger}} = B_{pa}$; $X_{MSY} = 0.5\ MSYR$
stk#.#.hcr7		$B_{MSY\text{-trigger}} = 1.5\ B_{pa}$; $X_{MSY} = 1.5\ MSYR$
stk#.#.hcr8		$B_{MSY\text{-trigger}} = 1.5\ B_{pa}$; $X_{MSY} = MSYR$
stk#.#.hcr9		$B_{MSY\text{-trigger}} = 1.5\ B_{pa}$; $X_{MSY} = 0.5\ MSYR$
stk#.#.#.err1	Error models	assuming I_y is log-normally distributed with median B_y/q and 30% CV, where B_y is the true stock size (note: q=1 and is held constant, while I_y could either be the total biomass or SSB index, in which case B_y would represent the corresponding quantity)
stk#.#.#.err2		As above, but q increases from 0.7 in year Y_{init} see Appendix 1) to 1 in year Y_{init}+30 (note: this increase is not directly accounted for by the HCR, which assumes it remains constant over time)

Organisation of Results:

Results have been organised into appendices for ease of comparison. Only cod-like scenarios are considered. Table 2 describes the contents of Appendices 2-4.

Appendix 2 explores the construction of the catch rule by switching on the various factors in the catch rule (equation 2), starting from the rule evaluated by De Oliveira et al. (2010); this was HCR4 in that study, and is reproduced here as "r.nof.nocnstr.nob" (referring to whether the various components of the catch rule are switched on or off – a prefix of "no" indicating off).

Appendix 3 subjects catch rule "r.f0.b0.cnstr" (no lag in *f* and *b* indicated by the "0", and TAC constraint switched on) to a full design that covers all possible combinations in Table 1 (72 in total). This catch rule is selected because it is one of the best performing options presented in Appendix 2, and if it does not perform adequately under the range of scenarios and HCR variants (reflecting uncertainty in the calculation of *f* and *b*) considered, then it is unlikely that any of the other options will perform adequately either.

Appendix 4 contrast four catch rules, each subject to 8 scenarios for the HCR variant that assumes an unbiased calculation of *f* and *b* ($X_{\text{MSY}} = MSYR$, and $B_{\text{MSY-trigger}} = B_{\text{pa}}$). The four catch rules refer to combinations of a 1-year lag or no lag in *f* and *b*, and the TAC constraint switched on or off: "r.f.nocnstr.b", "r.f.b.cnstr", "r.f0.b0.cnstr", and "r.f0.nocnstr.b0".

When comparisons are made, these are done in such a way that there is only one change between the plots that are compared (e.g. TAC constraint switched on or off, lag included or not, etc.) to aid understanding. Furthermore, for each set of four plots, representing SSB, yield, harvest rate F and recruitment, the red horizontal line represents the corresponding MSY value, the solid black line, the median trajectory, and the hashed in dotted lines the inner and outer quantiles.

Table 2. Description of Appendices 2-4.

General Description	Details
Appendix 2 construction of catch rule [using hcr5: $B_{MSY\text{-}trigger} = B_{pa}$; $X_{MSY} = MSYR$]	
<u>Switching factors on/off</u>	
r.nof.nocnstr.nob	Base comparison (all but *r* switched off)
r.nof.nocnstr.b	Switch on *b*
r.f.nocnstr.nob	Switch on *f*
r.f.nocnstr.b	Switch on both *b* and *f*
<u>*f* factor averaging</u>	
r.f.nocnstr.b	Base comparison (*f* as in eq. 4)
r.f2.nocnstr.b	C_{y-1} and I_{y-1}^{SSB} replaced by averages over *y*-2 to *y*-1
r.f3.nocnstr.b	C_{y-1} and I_{y-1}^{SSB} replaced by averages over *y*-3 to *y*-1
<u>Get rid of 1-year lag in *f* and *b*</u>	
r.f.nocnstr.b	Base comparison (*b* and *f* as in eqs 3 and 4)
r.f.nocnstr.b0	For *b*, replace *y*-1 with *y*
r.f0.nocnstr.b	For *f*, replace *y*-1 with *y*
r.f0.nocnstr.b0	For both *b* and *f*, replace *y*-1 with *y*
<u>Switch on TAC constraint</u>	
With 1-year lag in *f* and *b*	
r.f.nocnstr.b	Base comparison with 1-yr lag (TAC constraint off)
r.f.cnstr.b	Apply TAC constraint before *b*
r.f.b.cnstr	Apply TAC constraint after *b*
Without 1-year lag in *f* and *b*	
r.f0.nocnstr.b0	Base comparison without lag (TAC constraint off)
r.f0.cnstr.b0	Apply TAC constraint before *b*
r.f0.b0.cnstr	Apply TAC constraint after *b*
Appendix 3 Full Design (8 scenarios × 9 HCR options) based on r.f0.b0.cnstr	
stat1, err1 page 1: stk0.9 page 2: stk0.75 stat2, err1 page 1: stk0.9 page 2: stk0.75 stat1, err2 page 1: stk0.9 page 2: stk0.75 stat2, err2 page 1: stk0.9 page 2: stk0.75	On each page, 9 HCR variants, as shown in Table 1 for r.f0,b0.cnstr in Appendix 2 Central plots (hcr5) are subsequently used in Appendix 4 comparisons
Appendix 4 Scenarios only for hcr5 variant of r.f.nocnstr.b, r.f.b.cnstr, r.f0.b0.cnstr, r.f0.nocnstr.b0	
Page 1: stat1, err1 Page 2: stat2, err1 Page 3: stat1, err2 Page 4: stat2, err2	On each page: Columns: steepness (left=0.9, right=0.75 Rows: Appendix 2 options r.f.nocnstr.b, r.f.b.cnstr, r.f0.b0.cnstr and r.f0.nocnstr.b0

Results:

Appendix 2

1. Switching factors on/off

   Commencing with the top-left [tl] plot (HCR 4 in De Oliveira et al. 2010), switching *b* or *f* on (top-right [tr] or bottom-left [bl]) has the opposite effect in terms of *SSB* and *F* trends, although *yield* is in the same direction in each case. When both *b* and *f* are switched on (bottom-right [br]), the dominant effect is *f*.

2. *f* factor averaging

   Averaging *f* over 2 or 3 years (from *y*-2 or *y*-3 to *y*-1) accentuates cyclical behaviour (stronger as the average is taken further back), pointing to a problem with quality of the adjustment factors in terms of how up to date they are.

3. Get rid of 1-year lag in *f* and *b*

   Here, the 1-year is removed first from *b* (tr) and *f* (bl) then from both (br), so that the calculation of *b* and *f* occurs in the assessment year *Y* (Appendix 1). Although the removal of the lag from *b* has little effect, it causes a marked improvement in the performance of the HCR in its ability to achieve MSY levels when removed from *f*.

4. Switch on TAC constraint
   a. With 1-year lag in *f* and *b*

      In this case, switching the TAC constraint on has a positive effect on the performance of the HCR, which is also sensitive to the order in which *b* and the TAC constraint is applied: *b* applied last (bl) causes an over-compensation in SSB, while the TAC constraint applied last (br) allows the HCR to achieve MSY levels

   b. Without 1-year lag in *f* and *b*

      A similar pattern is observe here: applying *b* last (bl) causes a slight over-compensation in SSB, actually causing the HCR to perform worse in terms of achieving MSY levels than compared to have both the TAC constraint switched off (tl). Applying the TAC constraint last allows the HCR to achieve MSY levels, as before.

   A comparison of the bottom-right plots in 4a and b shows that, even though they both achieve MSY levels, the HCR with a 1-year lag in *b* and *f* has a greater number of low SSB levels, implying that a risk statistic such as "probability of $SSB < B_{MSY\text{-}trigger}$" would be substantially greater compared to an HCR without a lag in *b* and *f*.

Appendix 3

Focussing on the first page of Appendix 3a (stat1, err1, stk0.9), it is clear that a bias in *f* causes the HCR either to undershoot or overshoot the MSY target levels. Since *b* is effectively a precautionary scale-down factor (always ≤ 1), it has limited effect when there is no bias or a negative bias in *f*, but a positive bias in *b* does improve performance of the HCR when there is also a positive bias in *f*. This implies that the loss in yield due to a positive bias in *b* could potentially be more than compensated for by an improvement in risk to the resource in terms of improved SSB levels. Similar patterns are seen for a less productive stock (second page of Appendix 3a, stk0.75).

Appendix 3b explores the behaviour of the HCR when the stock is in an overfished state. When there is no bias in *f*, the HCR recovers the stock to MSY levels, achieving it more rapidly when there is a positive bias in *b*. As before, a bias in *f* causes the HCR to either undershoot or overshoot MSY levels, and in the case where there is a positive bias in *f*, a positive bias in *b* brings the HCR closer to the MSY levels for a more productive stock (first page of Appendix 3b), albeit with an initial loss in yield, but this is not apparent for the less productive stock (second page). A less productive stock also has a longer recovery time to MSY compared to the more productive stock.

The scenario and HCR variant runs of Appendix 3a and b ($q = 1$ and remains constant) are repeated in Appendix 3c and d for error model 2 (there is a trend in *q*, which has a value of 0.7 in the first assessment year Y_{init}, and a value of 1 in year Y_{init}+30). The impact of this trend in *q* is to give the HCR a moving target, so that whereas before the HCR was aiming for a fixed point, it now chases a target that changes from year to year, reaching MSY in the final year, the year that q = 1 (contrast hcr5 in the first page of Appendices 3a and c). Apart from this, the general patterns for Appendices 3c and d are the same as those in the corresponding Appendices 3a and b.

Appendix 4

Appendix 4 contrasts the performance of four HCRs (with/without 1-year lag in *b* and *f*, and with/without TAC constraint) across 8 scenarios, for the case where there is no bias in *b* and *f*, apart from the bias caused by a trend in *q* (pages 3 and 4 of Appendix 4 only). For the case where there is no trend in *q* (first two pages), three of the four HCRs achieve MSY targets, the exception being where there is a 1-year lag in *b* and *f*, and no TAC constraint is applied (top row of plots). Where a TAC constraint is applied, the difference in the no-lag vs. 1-year lag HCRs is in the greater number of low SSBs and the wider variation in trends for the latter. Similar patterns are evident where there is a trend in *q* (pages 3 and four).

Conclusions:

- Unbiased estimates of MSYR, exploitation rate and survey catchability are needed for the catch rule to deliver MSY targets
- Where a 1-year lag in the calculation of factor *f* is unavoidable:
- a TAC constraint is needed to stabilise the HCR
- there are a greater number of low SSB values compared to the HCR with no lag, implying a substantially greater risk of e.g. SSB<B_{lim}
- When applying factor *b* in combination with the TAC constraint, it is better to set $B_{MSY\text{-}trigger}$ too high than too low

References:

De Oliveira, J.A.A., Darby, C.D., Earl, T.J. and C.M. O'Brien. 2010. Technical Background Evaluation of Annex IV Rules. ICES CM 2010/ACOM:58: 28 pp.

STECF 2008. Annex I. STECF/ SGRST-08-02 Working Group Report on Harvest Control Rules, Lowestoft, 9-13 June 2008. p9-82. In: Subgroup on stock reviews of the STECF. STECF opinion expressed during the plenary meeting of 7-11 July 2008, Helsinki.

Appendix 1 Pseudo-code

A description of the calculation of *r* used in the simplified catch rule is provided in the form of pseudo-code.

Assume that:

Y-1 = last data year

Y = assessment year

Y+1 = year for which TAC is being set

Y_{init} = first of the Y values considered in each simulation

Calculation of r

Assume that a survey time series of total biomass is available to be used directly in the calculation of *r*. This is derived from the operating model with observation error, to give a time series relative index I_y of total biomass.

For the assessment year Y_{init} only, calculate $TAC_{Y_{init}+1}$ by doing a short-term forecast to the beginning of year Y_{init}+1, assuming GM recruitment, 3-year average selection- and mean weight-at-age, and $F_{Y_{init}} = F_{SQ}$

Apply the following steps:

1. Calculate $B_{now} = (I_{Y-1}+I_{Y-2})/2$
2. Calculate $B_{ref} = (I_{Y-3}+I_{Y-4}+I_{Y-5})/3$
3. Calculate *r* as:

$$r = \begin{cases} 1+\beta & , B_{now}/B_{ref} > 1+\alpha \\ \mathrm{f}(B_{now}/B_{ref}) & , 1-\alpha \le B_{now}/B_{ref} \le 1+\alpha \\ 1-\beta & , B_{now}/B_{ref} < 1-\alpha \end{cases}$$

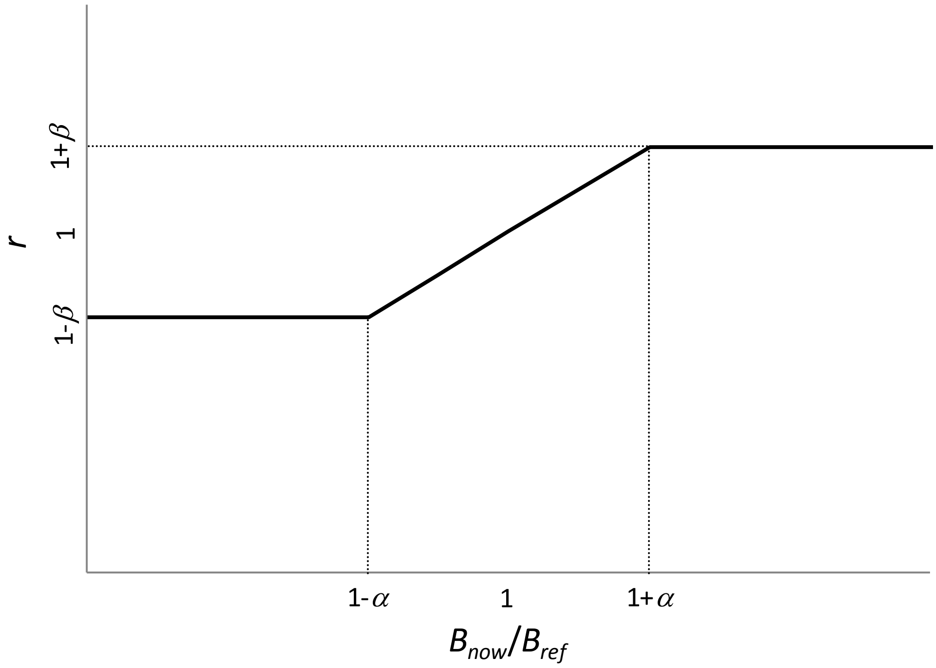
where f is a function of B_{now}/B_{ref}

For the HCRs considered in this study, □= 0.2 and □= 0.15.

For the implementation considered in this study (similar to HCR 4, the biomass linear transition rule, in De Oliveira *et al*. 2010), *r* is a linear transition function with

f (B_{now}/B_{ref}) = □(B_{now}/B_{ref} - 1)/□+ 1

The derivation of *r* used in the simplified catch rule is illustrated in Figure 1.



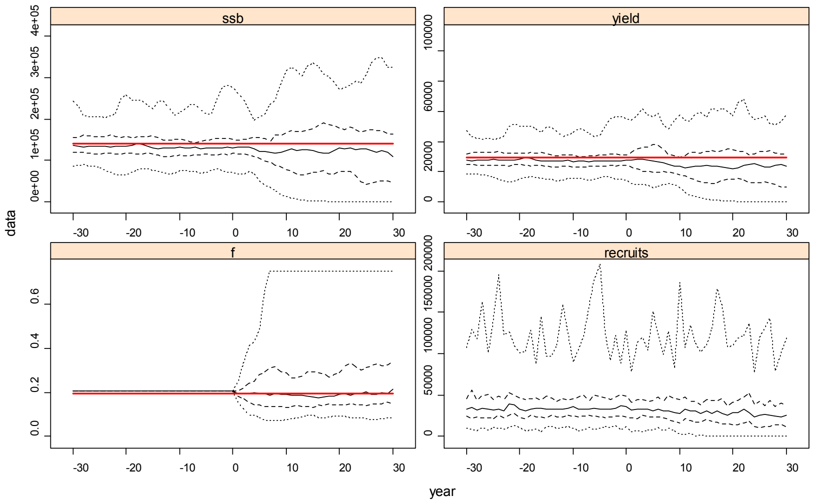
2

Figure A1.1 Illustration of the calculation of *r* used in the simplified catch rule

Appendix 2

1. Switching factors on/off

cod0.9.stat1.hcr5.err1.r.nof.nocnstr.nob



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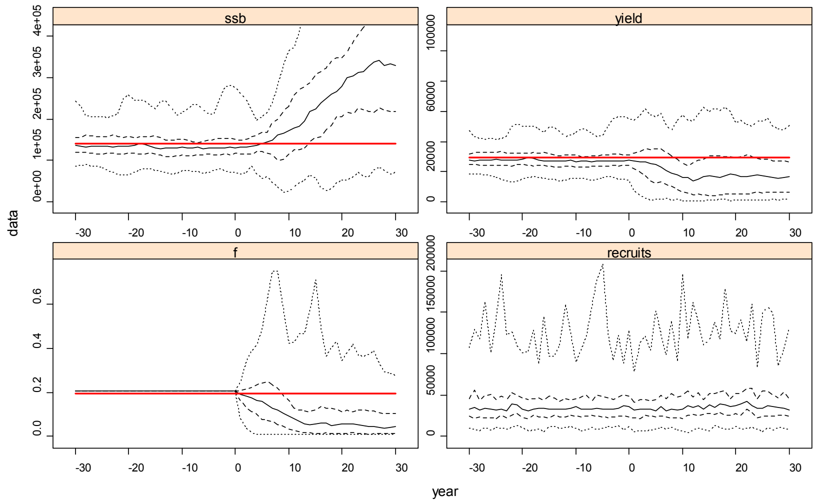

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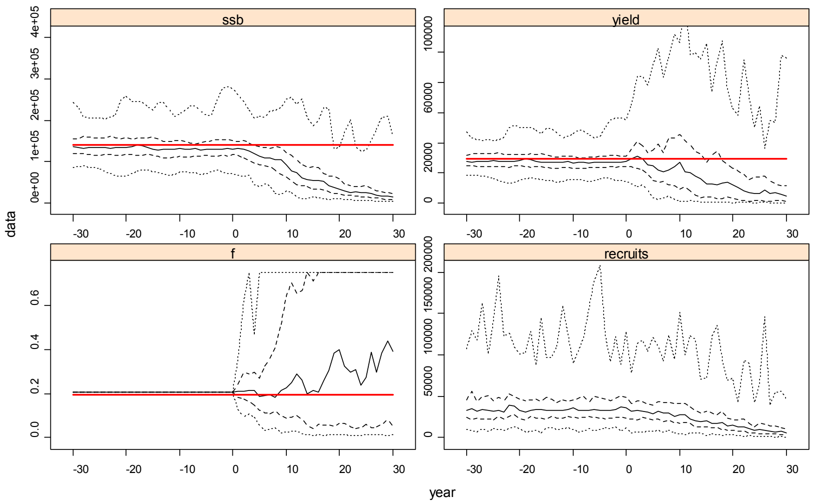

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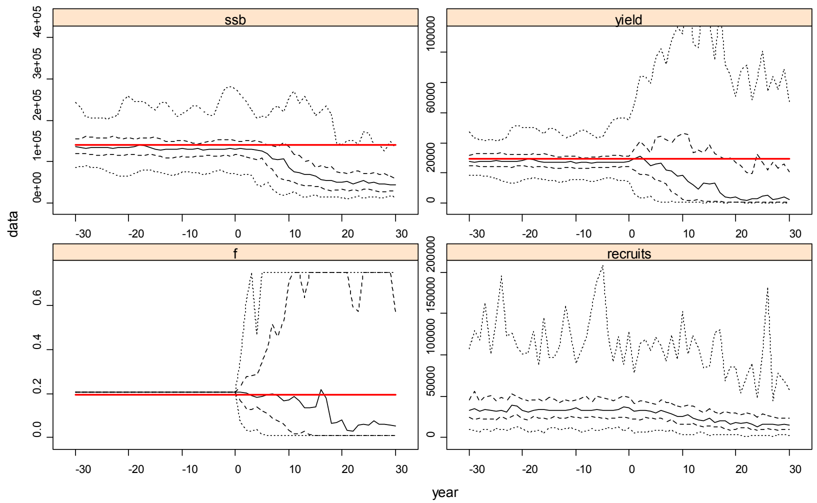
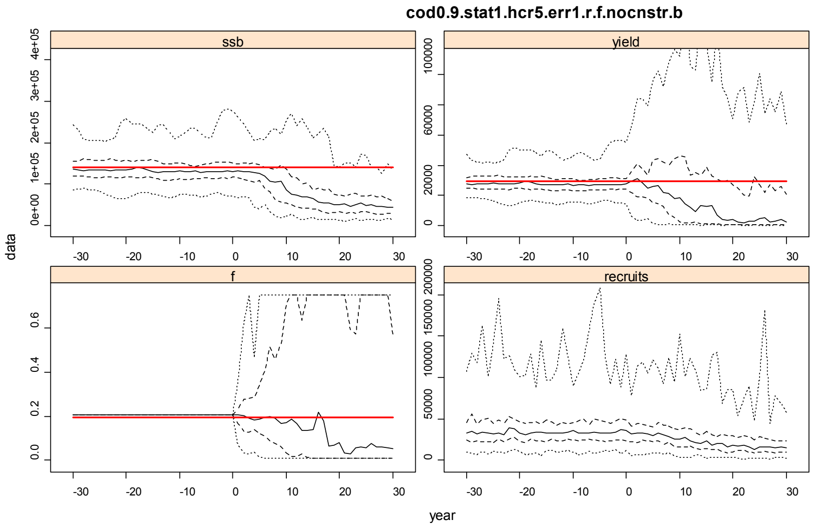
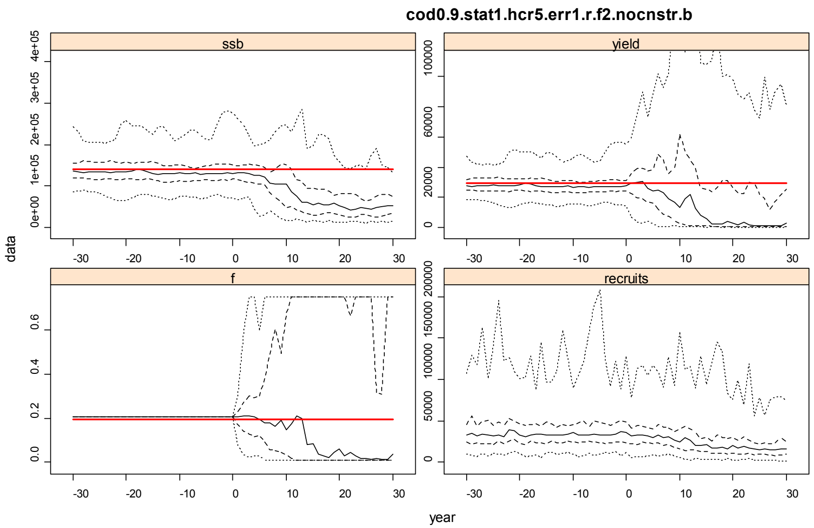
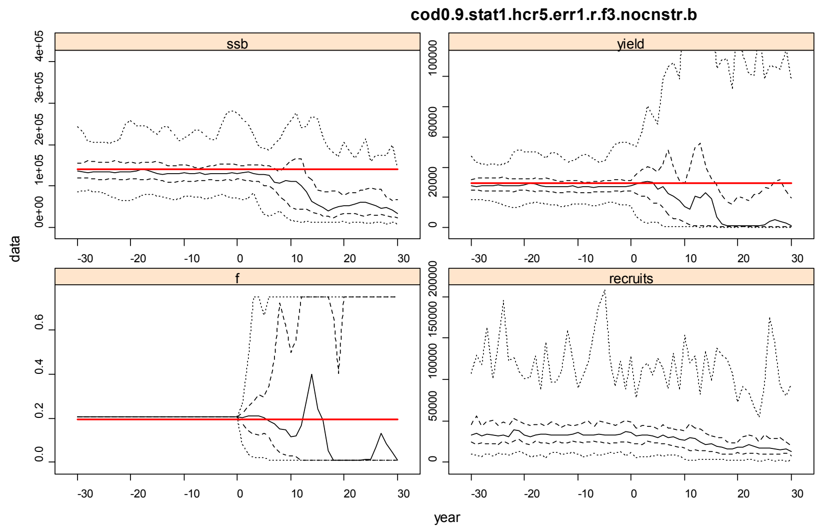


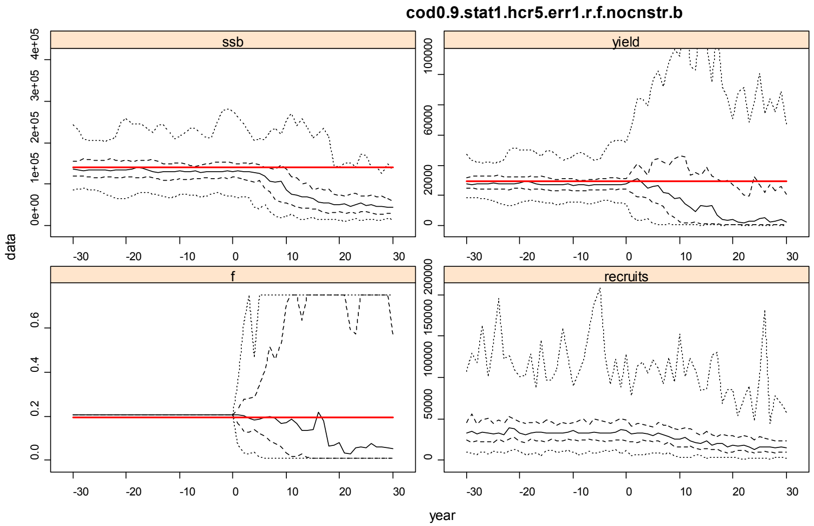
2. f factor averaging

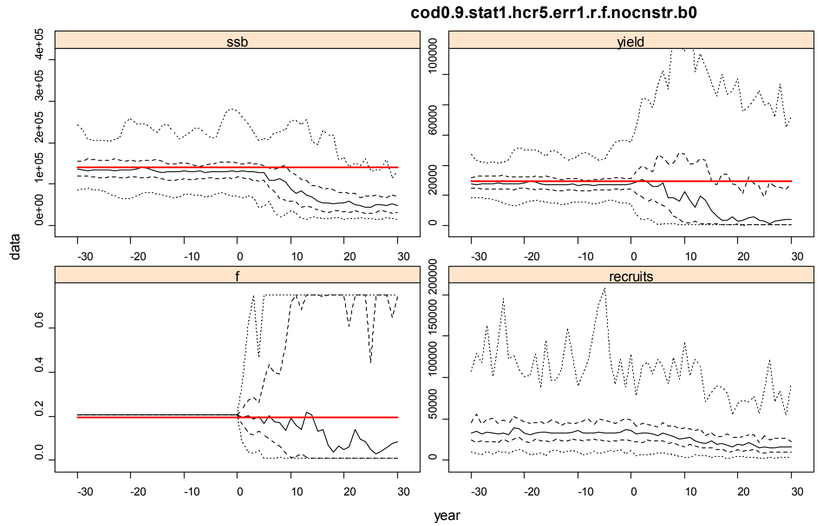


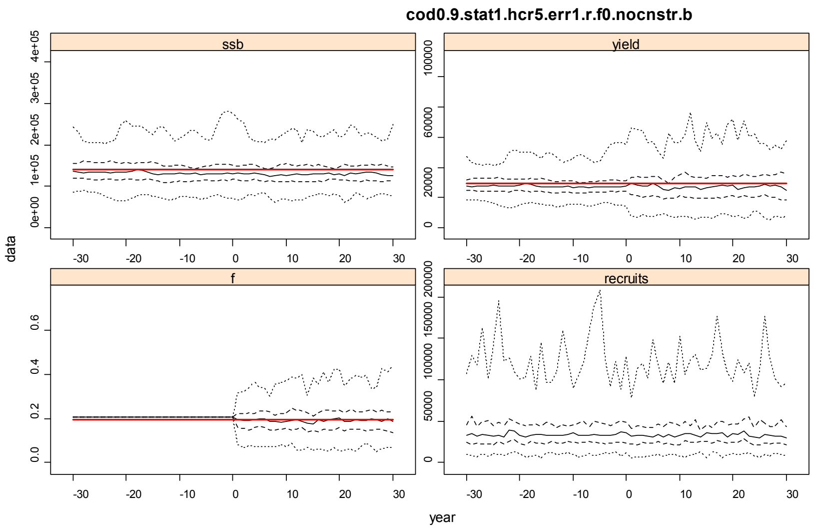


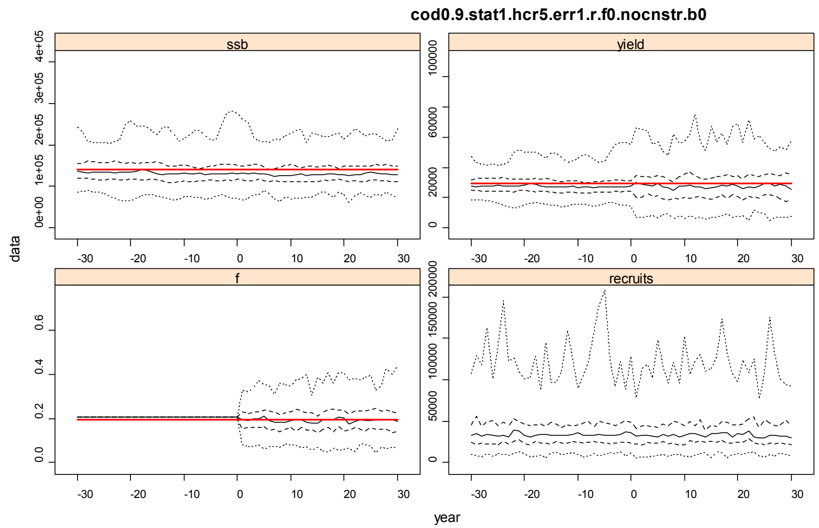


3. Get rid of 1-year lag in f and b

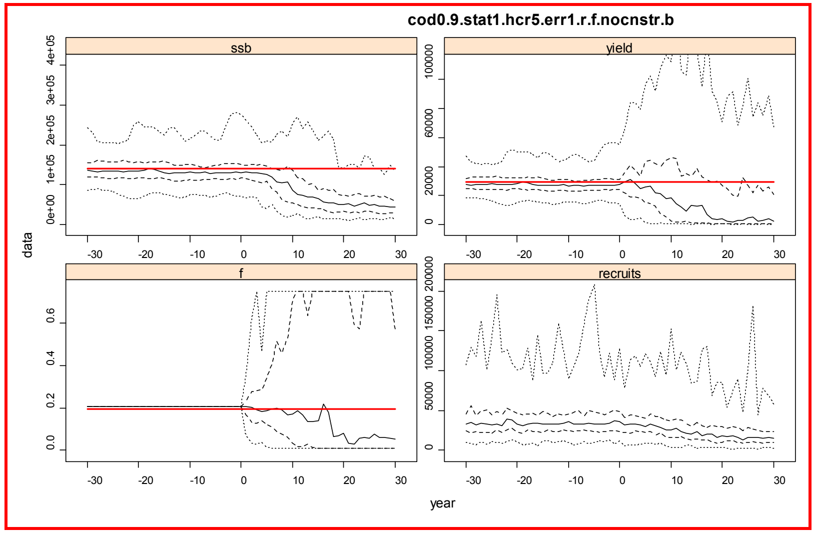


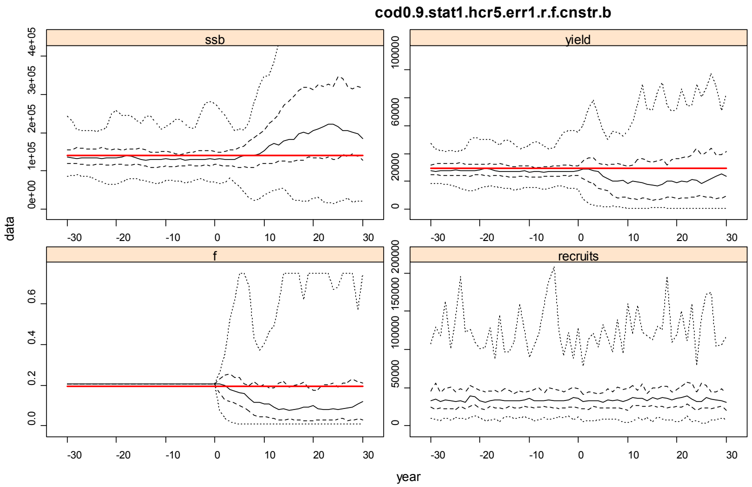


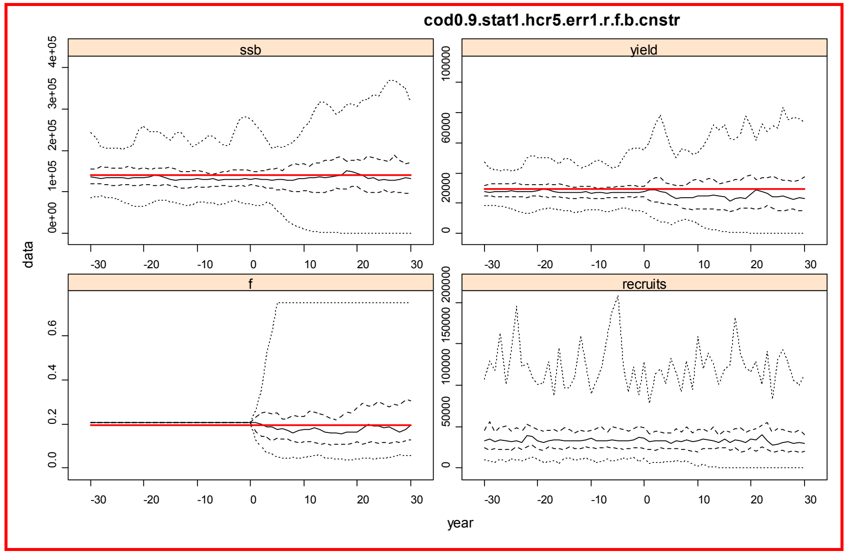




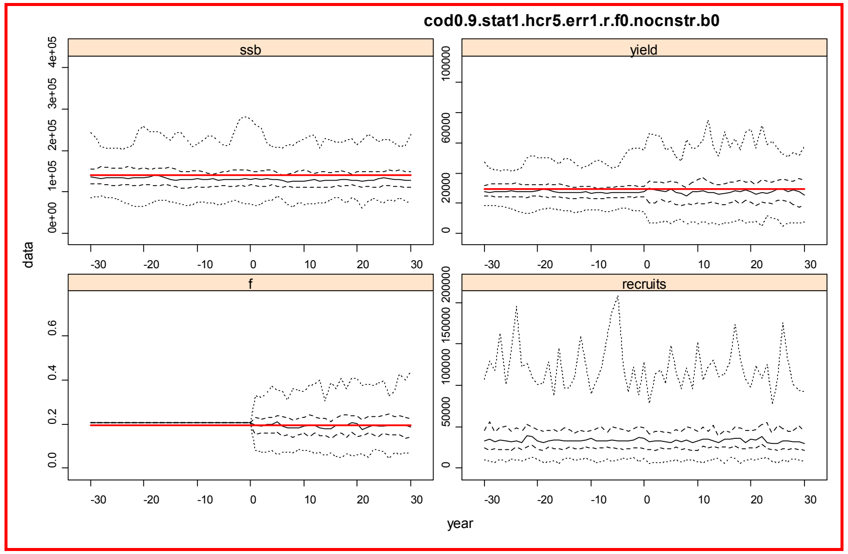
4a. Switch on TAC constraint (with 1-year lag in f and b)

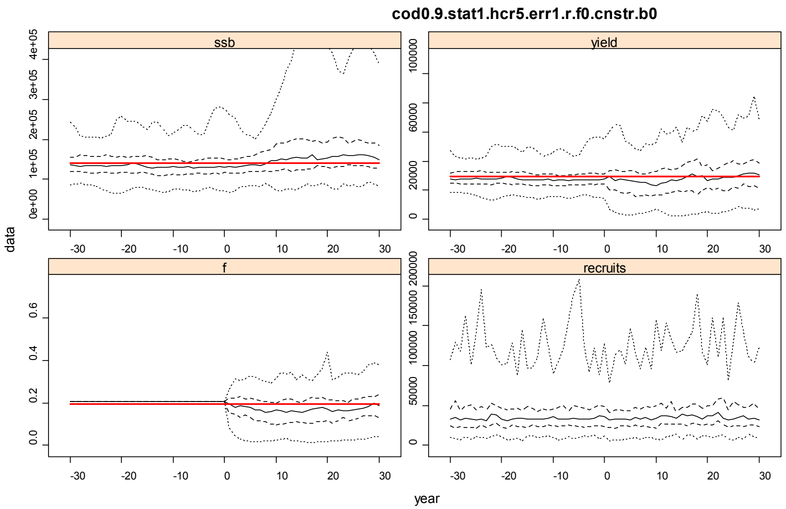


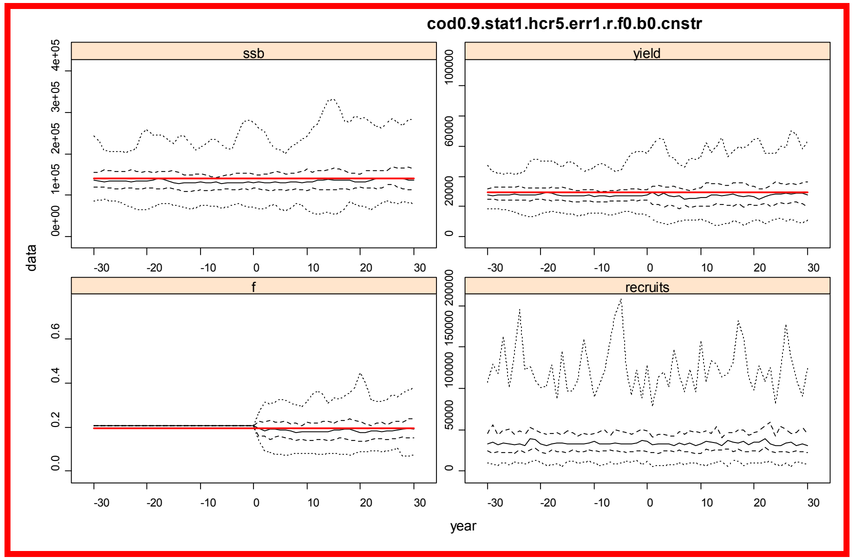




4b. Switch on TAC constraint (without 1-year lag in f and b)



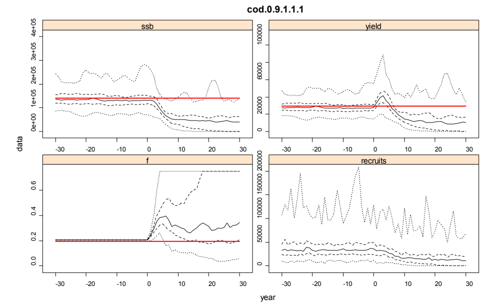


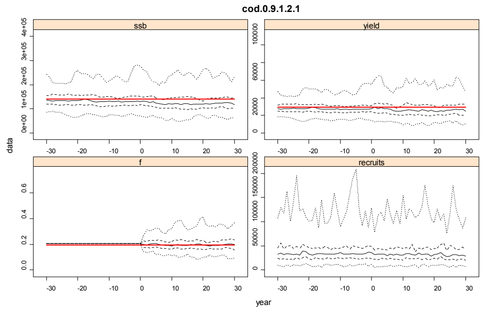


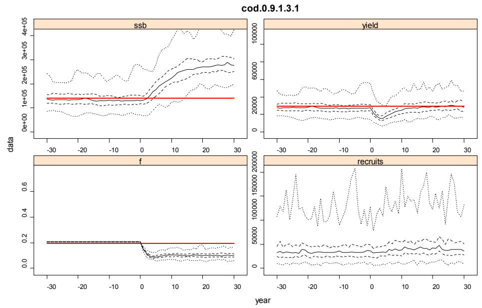
Appendix 3a (statl, err1)

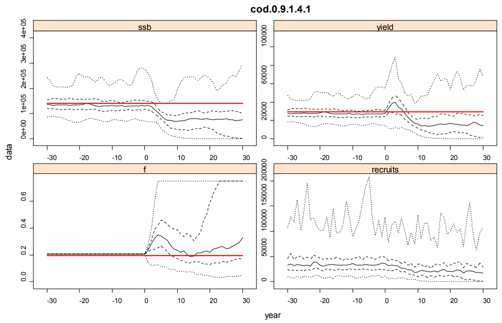
stk0.9 | 1.5 *MSYR* | *MSYR* | 0.5 *MSYR*

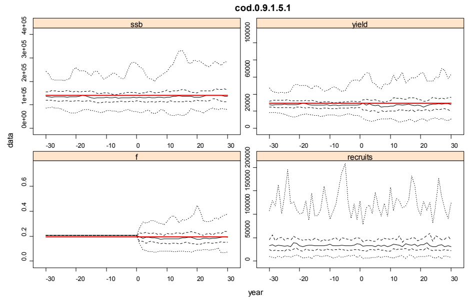
0.5 B_{pa}

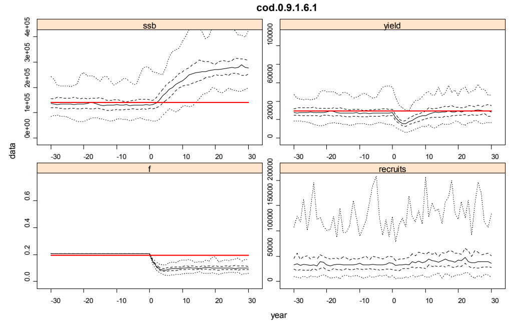




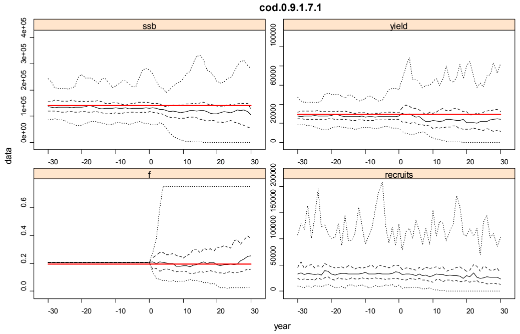


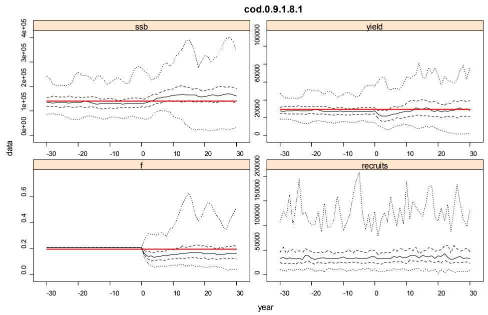


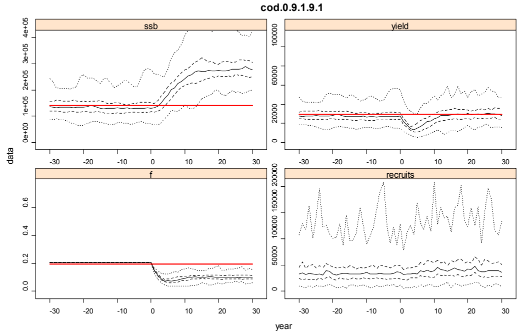




1.5 B_{pa}


cod.0.9.1.7.1
ssb
yield
f
recruits
data
year

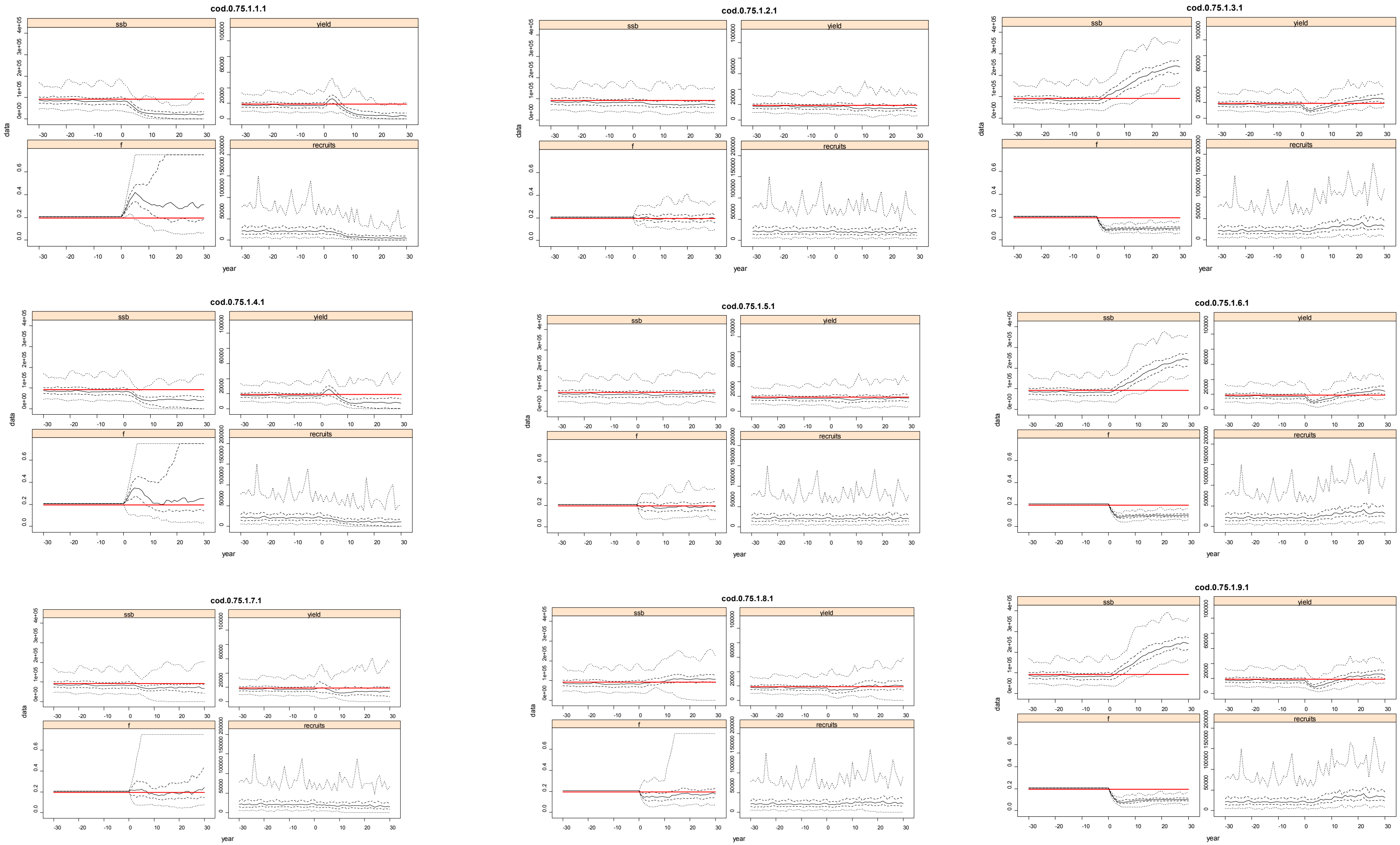

cod.0.9.1.8.1
ssb
yield
f
recruits
data
year


cod.0.9.1.9.1
ssb
yield
f
recruits
data
year

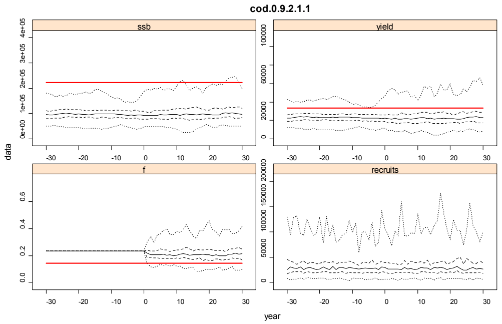
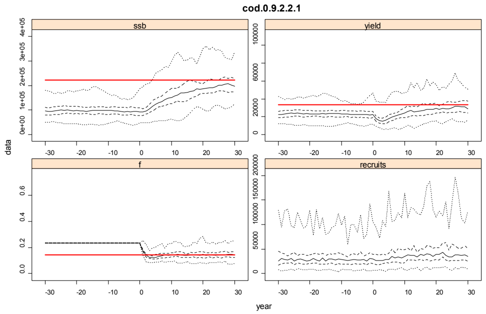
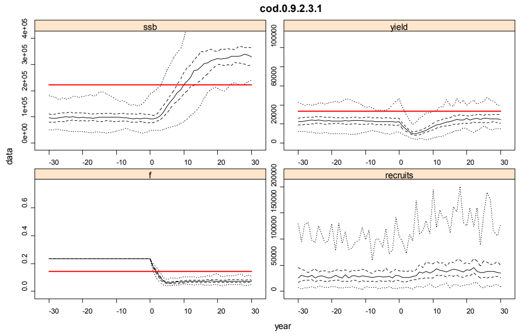
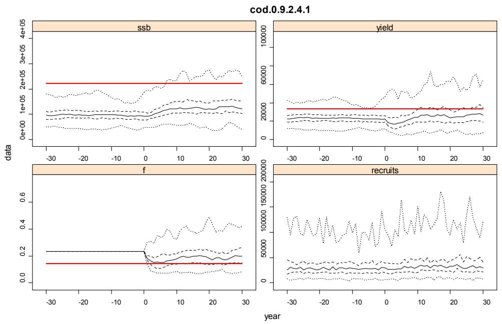
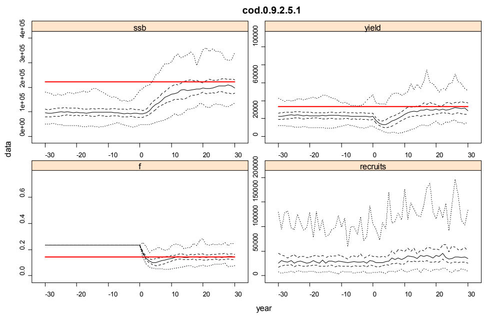
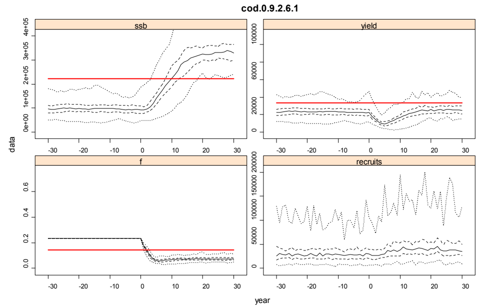
stk0.75

1.5 *MSYR* | *MSYR* | 0.5 *MSYR*

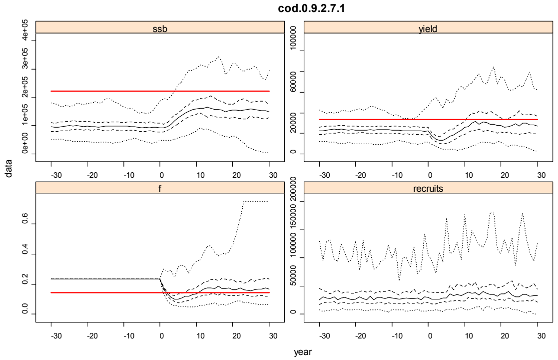
Rows: 0.5 B_{pa} | B_{pa} | 1.5 B_{pa}

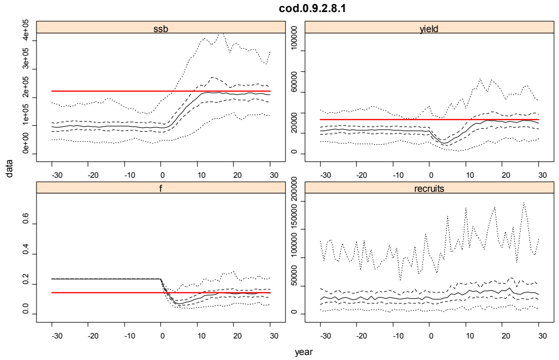


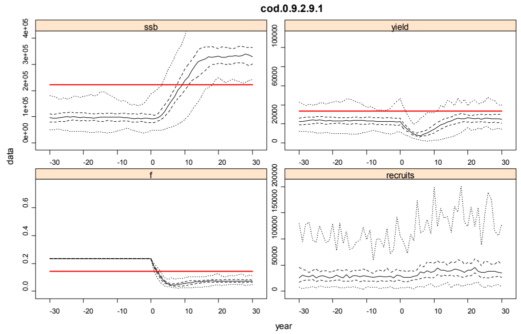
Appendix 3b (stat2, errl)

stk0.9	1.5 *MSYR*	*MSYR*	0.5 *MSYR*
0.5 B_{pa}			
B_{pa}			

$1.5\ B_{pa}$

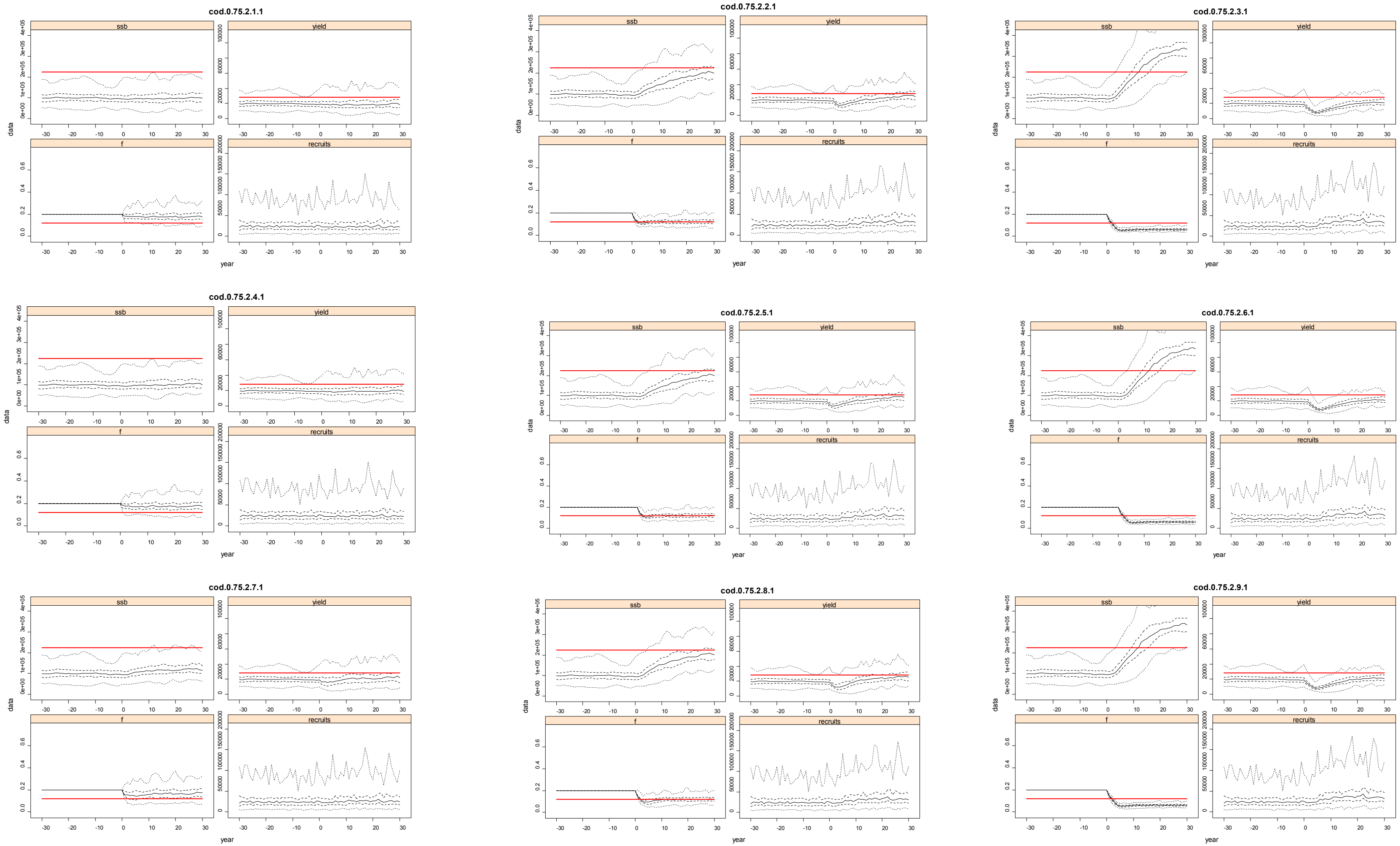

cod.0.9.2.7.1
ssb
yield
f
recruits
data
year


cod.0.9.2.8.1
ssb
yield
f
recruits
data
year


cod.0.9.2.9.1
ssb
yield
f
recruits
data
year

stk0.75 | 1.5 *MSYR* | *MSYR* | 0.5 *MSYR*

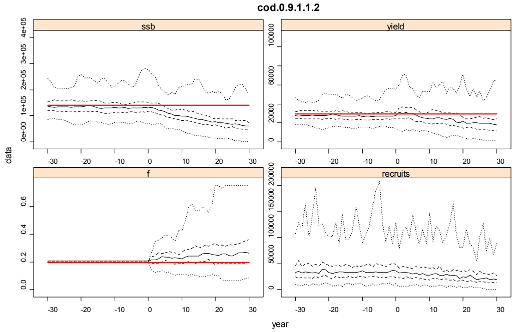
Rows: 0.5 B_{pa} | B_{pa} | 1.5 B_{pa}

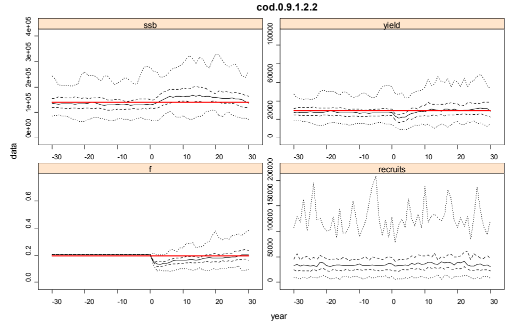


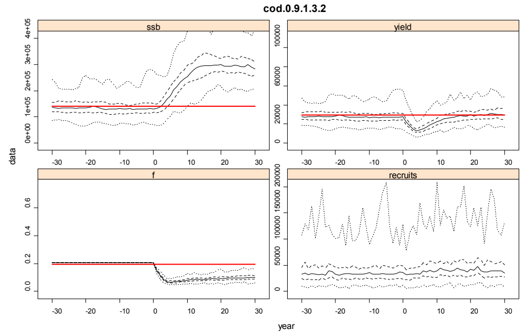
Appendix 3c (statl, err2)

stk0.9 1.5 *MSYR* *MSYR* 0.5 *MSYR*

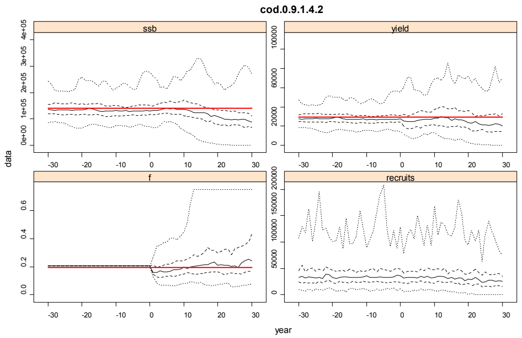
0.5 B_{pa}

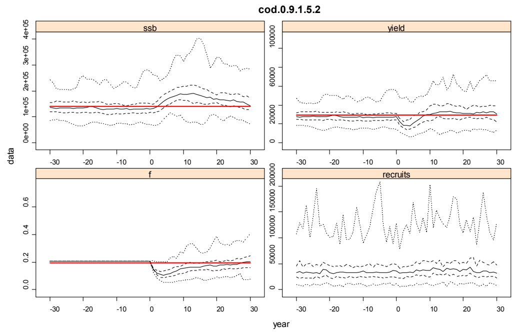


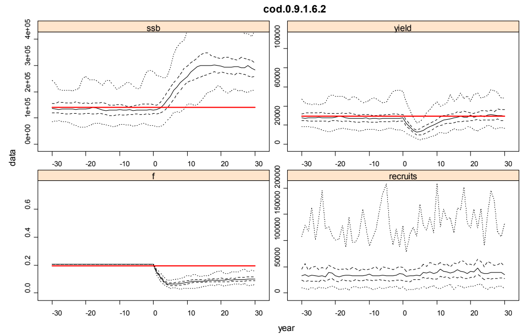




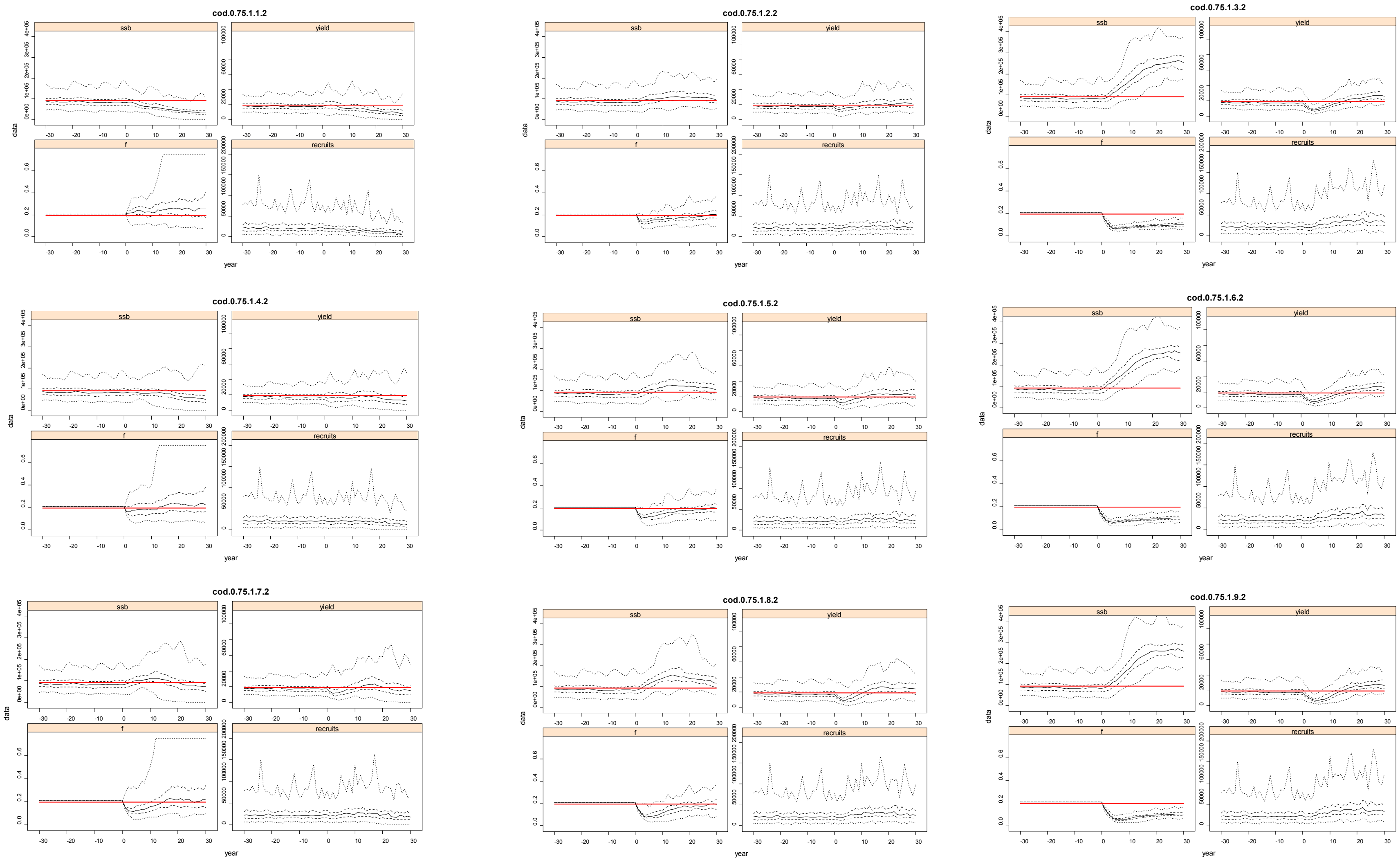
B_{pa}







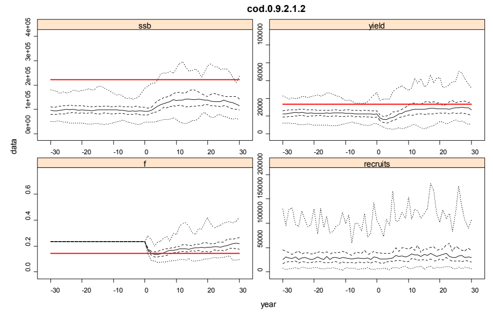
stk0.75	1.5 *MSYR*	*MSYR*	0.5 *MSYR*
0.5 B_{pa}	cod.0.75.1.1.2	cod.0.75.1.2.2	cod.0.75.1.3.2
B_{pa}	cod.0.75.1.4.2	cod.0.75.1.5.2	cod.0.75.1.6.2
1.5 B_{pa}	cod.0.75.1.7.2	cod.0.75.1.8.2	cod.0.75.1.9.2

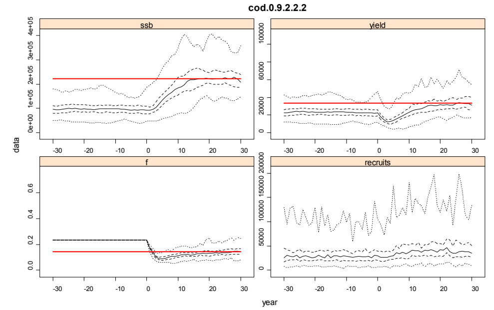


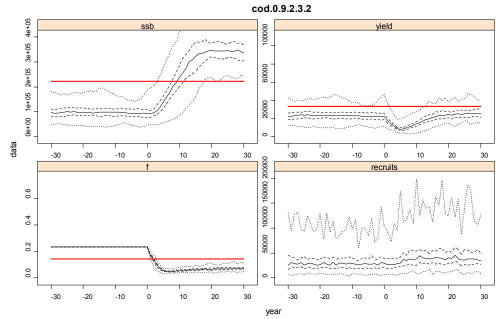
stk0.9

1.5 *MSYR* | *MSYR* | 0.5 *MSYR*

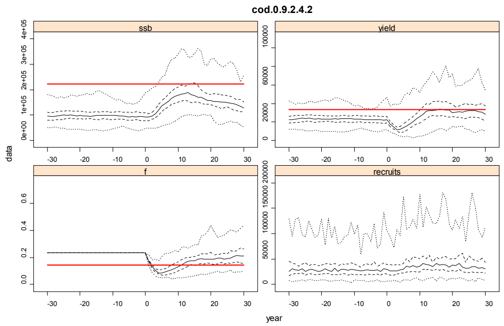
$0.5\ B_{pa}$

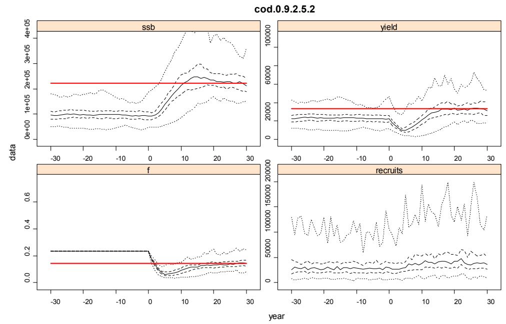


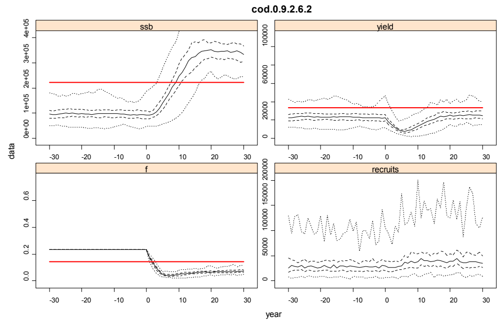




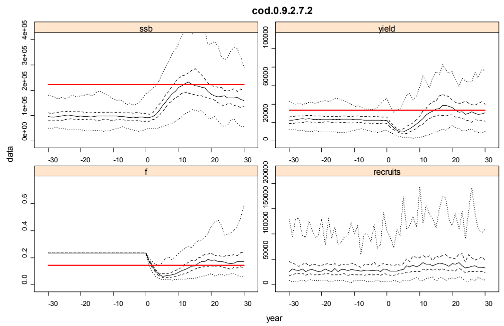
B_{pa}

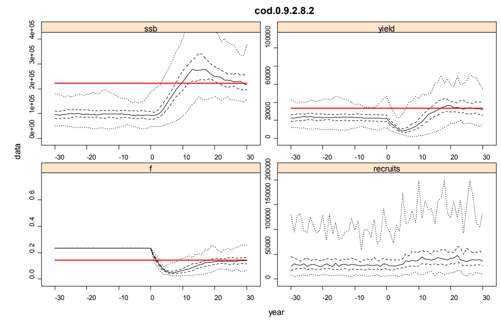


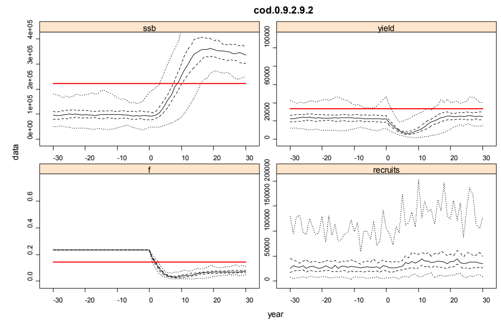




$1.5\ B_{pa}$



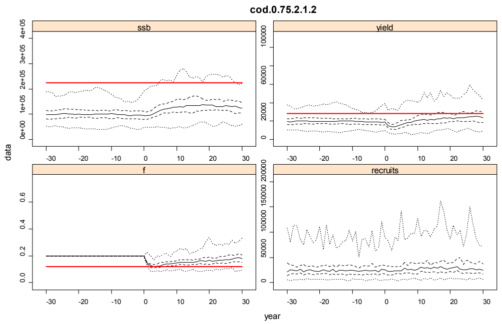


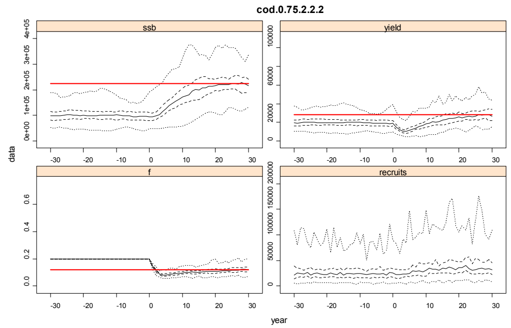


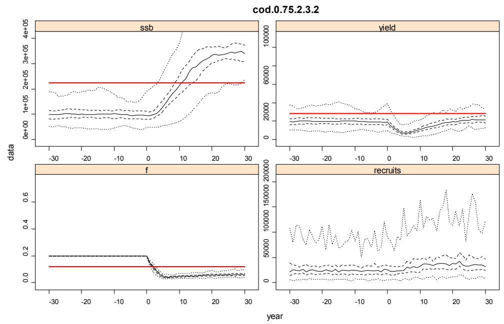
stk0.75

1.5 *MSYR* | *MSYR* | 0.5 *MSYR*

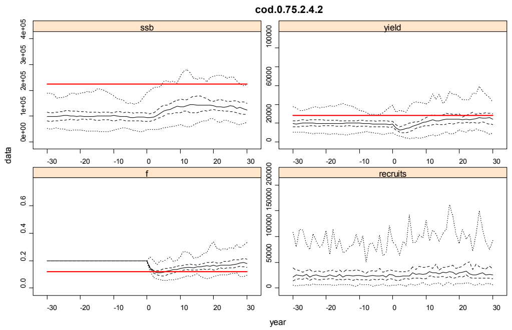
0.5 B_{pa}

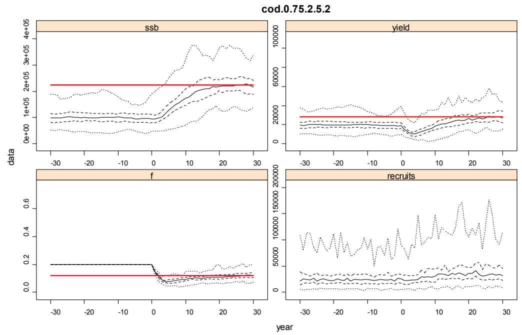


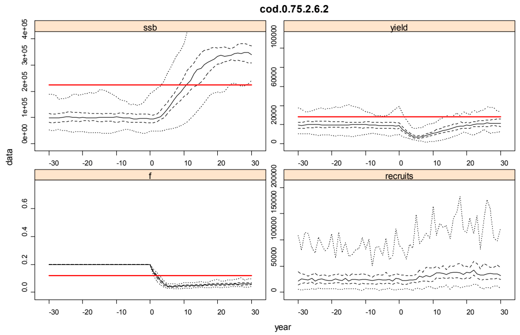




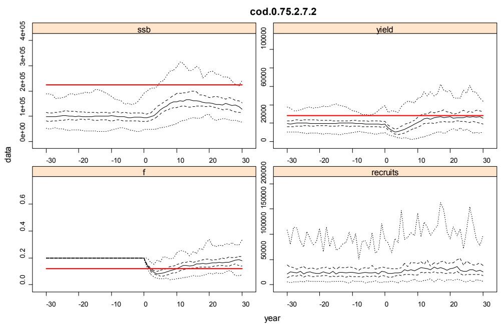
B_{pa}

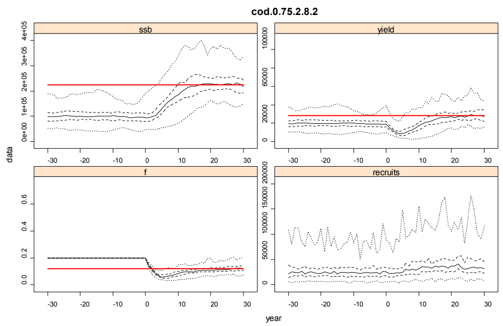


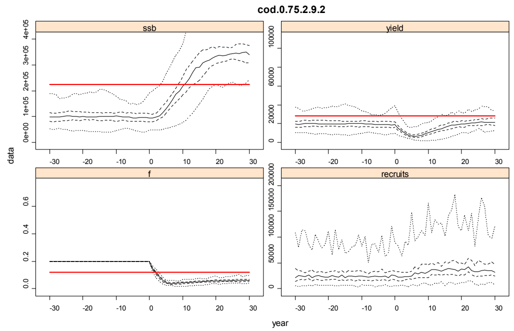




1.5 B_{pa}





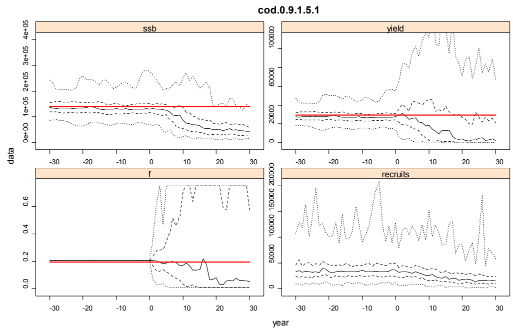


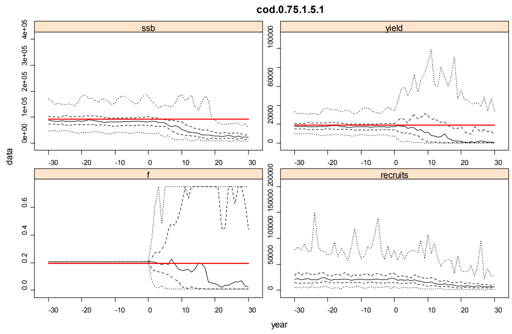
Appendix 4

<u>stat1, err1</u>

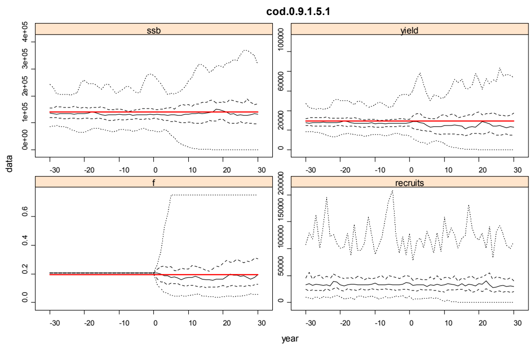
Steepness=0.9 Steepness=0.75

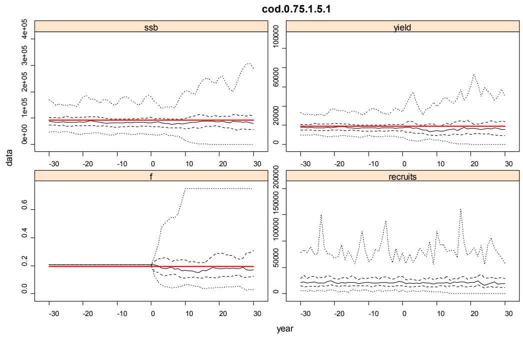
1-yr Lag; No TAC cnstr



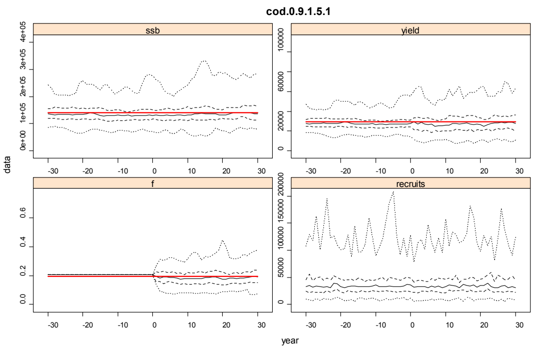


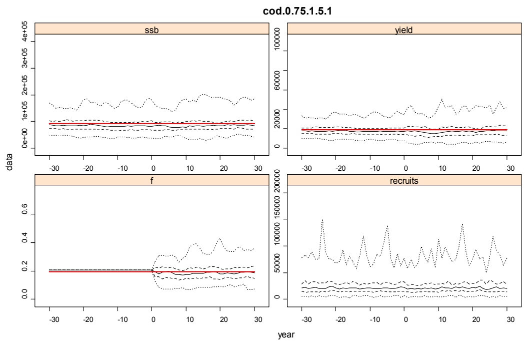
1-yr Lag; With TAC cnstr



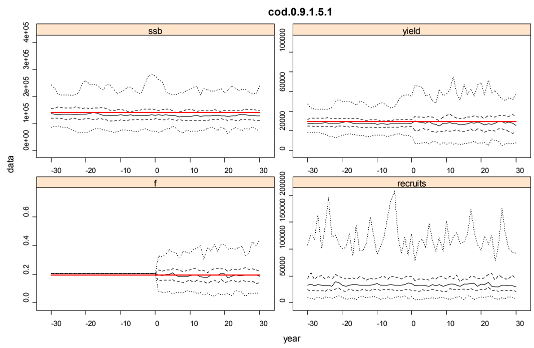


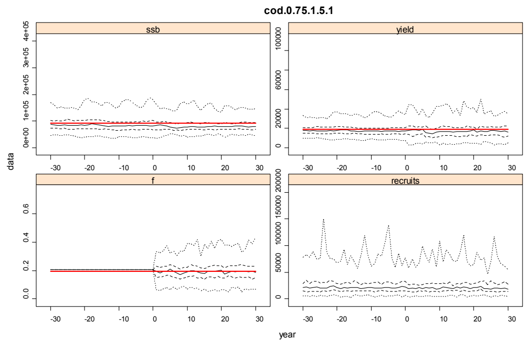
No Lag, With TAC cnstr





No Lag, No TAC cnstr

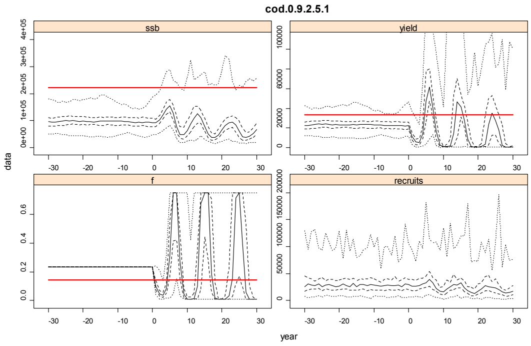


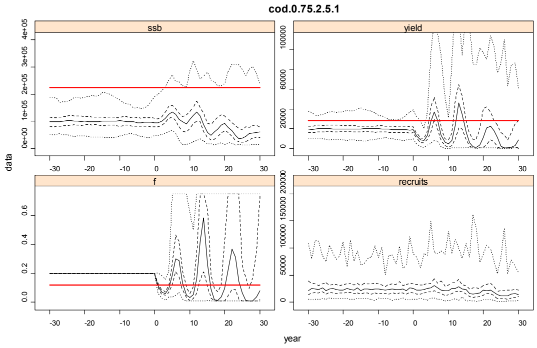


stat2, err1

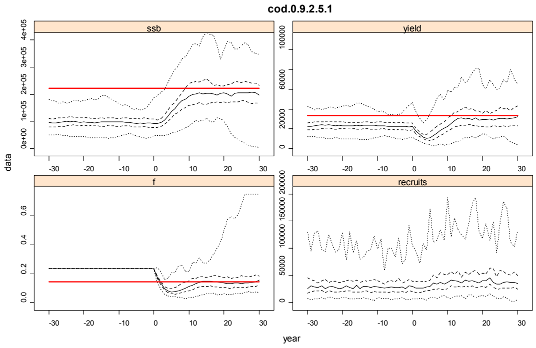
Steepness=0.9 Steepness=0.75

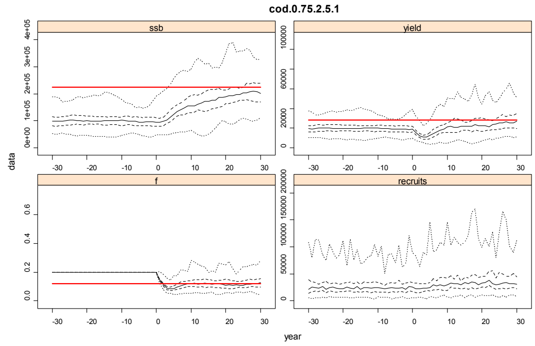
1-yr Lag; No TAC cnstr



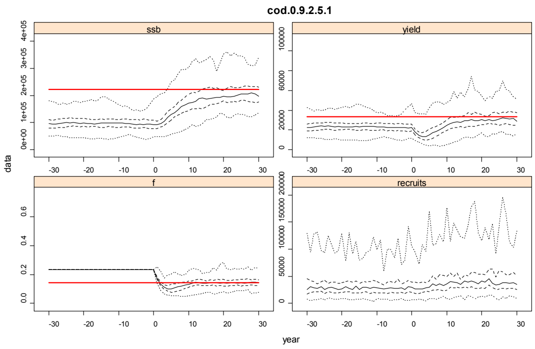


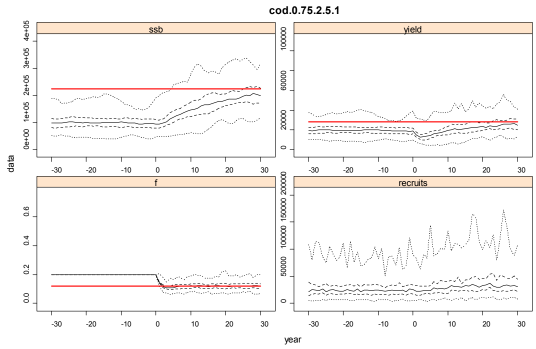
1-yr Lag; With TAC cnstr



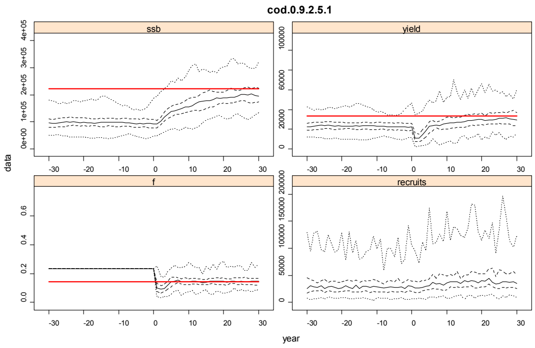


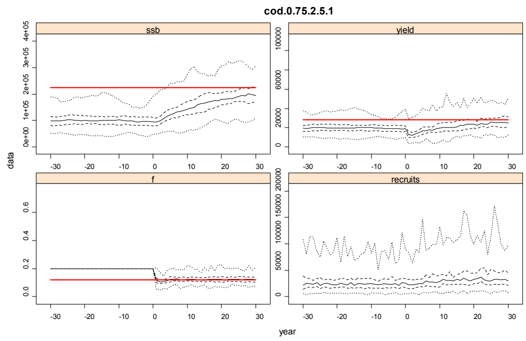
No Lag, With TAC cnstr





No Lag, No TAC cnstr

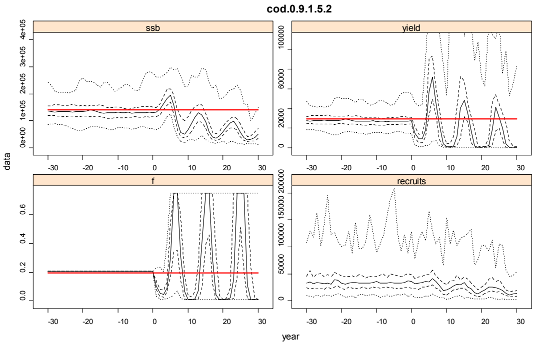


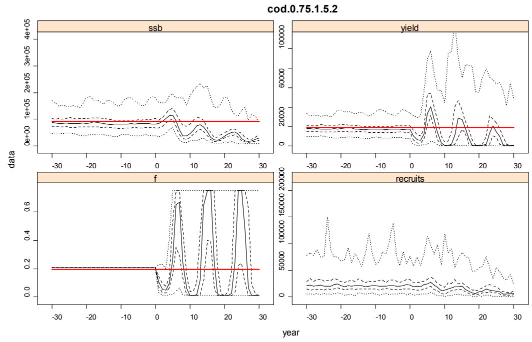


<u>stat1, err2</u>

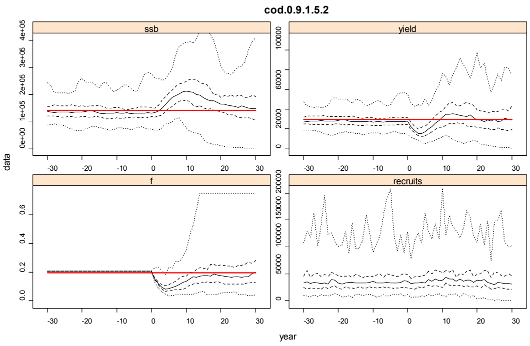
Steepness=0.9 Steepness=0.75

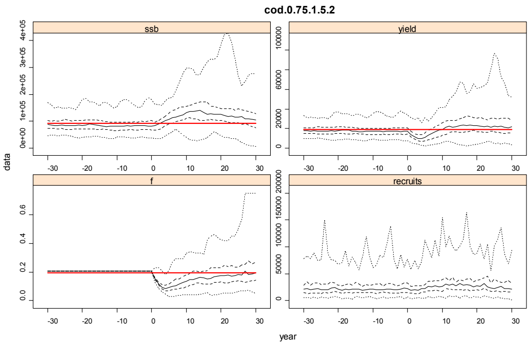
1-yr Lag; No TAC cnstr



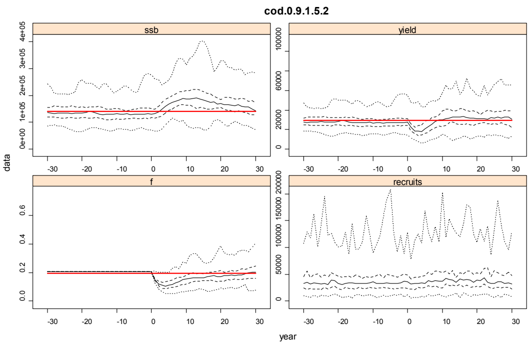


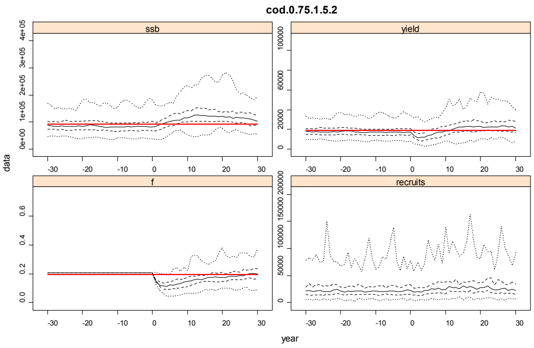
1-yr Lag; With TAC cnstr



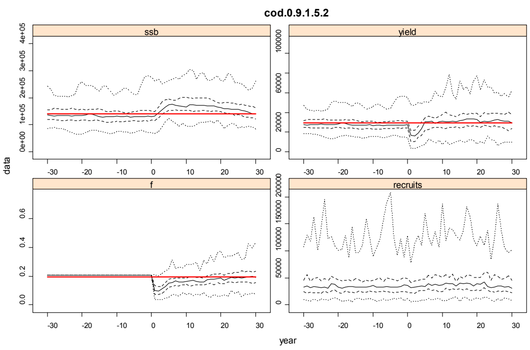


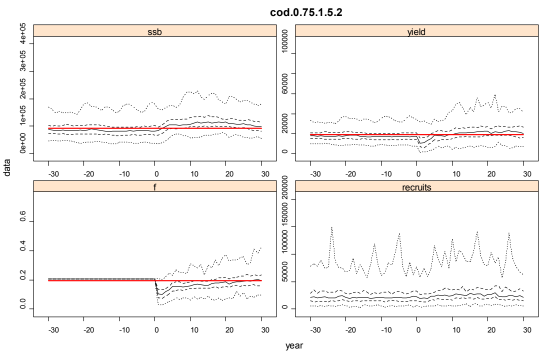
No Lag, With TAC cnstr





No Lag, No TAC cnstr

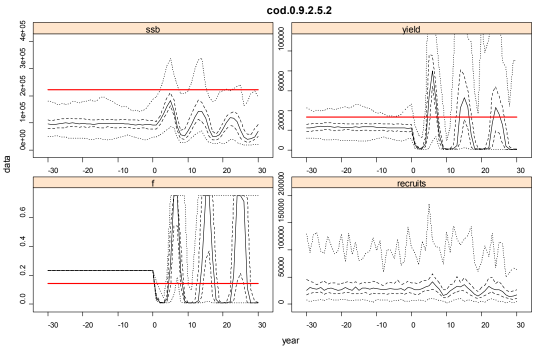


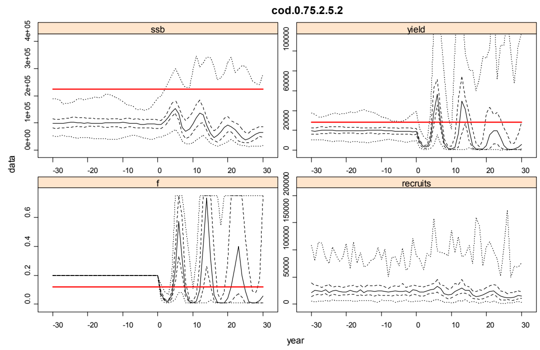


stat2, err2

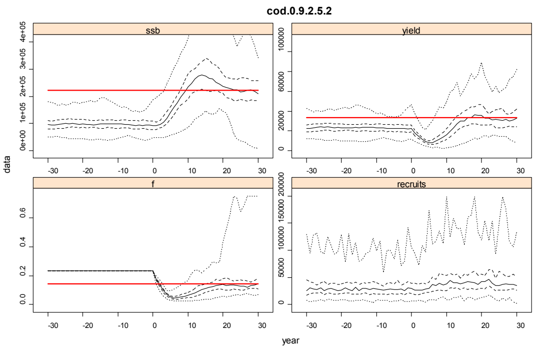
Steepness=0.9 Steepness=0.75

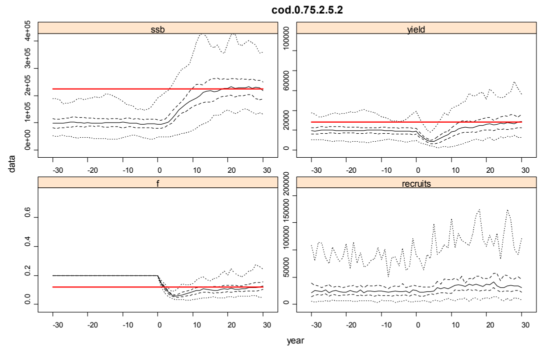
1-yr Lag; No TAC cnstr



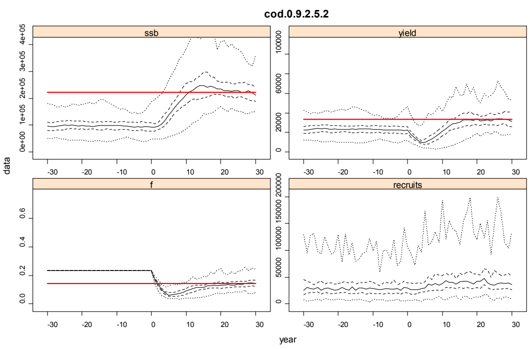


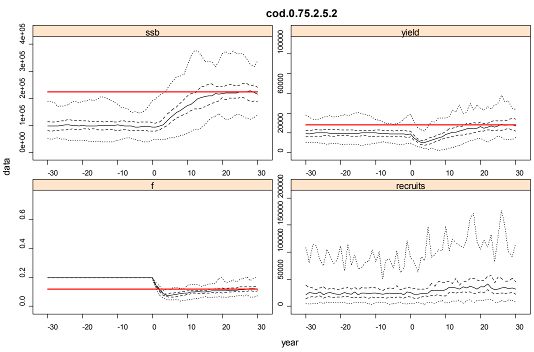
1-yr Lag; With TAC cnstr



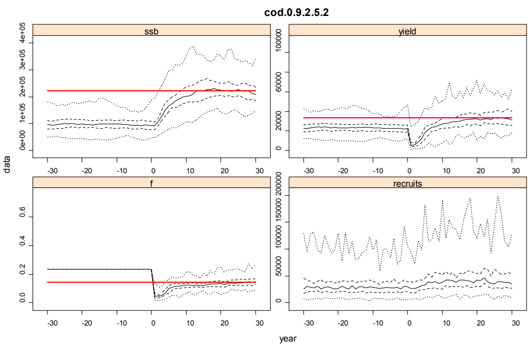


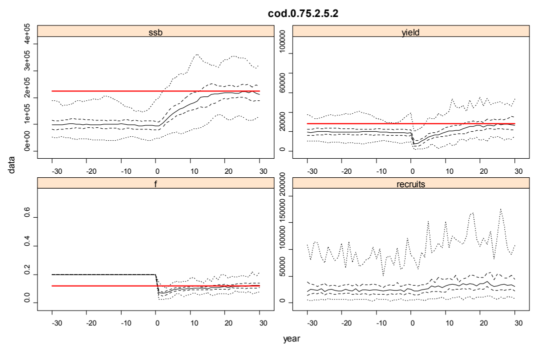
No Lag, With TAC cnstr





No Lag, No TAC cnstr





Annex E: R code for *gislasim()* and *lh()* functions

R code below for *gislasim()* and *lh()* functions. Code under development, current version available at https://r-forge.r-project.org/scm/viewvc.php/*checkout*/pkg/FLAdvice/R/lh.R?root=flr

```
gislasim function (par, sl = 5, sr = 5000)
{
    names(dimnames(par)) = tolower(names(dimnames(par)))
    if (!("t0" %in% dimnames(par)$params))
        par = rbind(par, FLPar(t0 = 0))
    if (!("a" %in% dimnames(par)$params))
        par = rbind(par, FLPar(a = 0.01))
    if (!("b" %in% dimnames(par)$params))
        par = rbind(par, FLPar(b = 3))
    if (!("k" %in% dimnames(par)$params))
        par = rbind(par, FLPar(k = exp(0.5236 + c(log(par["linf"])) *
            -0.454)))
    par = FLPar(rbind(par, FLPar(c(a50 = exp(0.8776 * log(par["linf",
        ]) - 0.038), ato95 = 0, asym = 1))))
    par["a50"] = invVonB(par, c(par["a50"]))
    par = rbind(par, FLPar(a1 = par["a50"], sl = sl, sr = sr))
    return(par)
}
<environment: namespace:FLAdvice>


lh function (par, growth = vonB, fnM = function(par, len, T = 290,
    a = FLPar(c(-2.1104327, -1.7023068, 1.5067827, 0.9664798,
        763.5074169))) exp(a[1] + a[2] * log(len) + a[3] *
log(par["linf"]) +
    a[4] * log(par["k"]) + a[5]/T), fnMat = logistic, selFn = dnormal,
    sr = list(model = "bevholt", steepness = 0.9, vbiomass = 1000),
    age = 1:40 + 0.5, T = 290, ...)
{
    age = FLQuant(age, dimnames = list(age = floor(age)))
    len = growth(par[c("linf", "t0", "k")], age)
    wts = par["a"] * len^par["b"]/1000
    m. = fnM(par = par, len = len, T = T)
    mat. = fnMat(par, age)
    sel. = selFn(par, age)
    dms = dimnames(m.)
    res = FLBRP(stock.wt = wts, landings.wt = wts, discards.wt = wts,
        bycatch.wt = wts, m = m., mat = FLQuant(mat., dimnames = dim-
names(m.)),
        landings.sel = FLQuant(sel., dimnames = dimnames(m.)),
```

```
        discards.sel = FLQuant(0, dimnames = dimnames(m.)), by-
catch.harvest = FLQuant(0,
            dimnames = dimnames(m.)), harvest.spwn = FLQuant(0,
            dimnames = dimnames(m.)), m.spwn = FLQuant(0, dimnames =
dimnames(m.)),
        availability = FLQuant(1, dimnames = dimnames(m.)))
    wtSlots <- c("stock.wt", "landings.wt", "discards.wt", "by-
catch.wt")
    for (wtSlot in wtSlots) units(slot(res, wtSlot)) <- "kg"
    range(res, c("minfbar", "maxfbar"))[] <-
as.numeric(dimnames(landings.sel(res)[landings.sel(res) ==
        max(landings.sel(res))][1])$age)
    args <- list(...)
    for (slt in names(args)[names(args) %in%
names(getSlots("FLBRP"))[names(getSlots("FLBRP")) !=
        "fbar"]]) slot(res, slt) <- args[[slt]]
    model(res) = do.call(sr$model, list())$model
    params(res) = FLPar(abPars(sr$model, spr0 = spr0(res), s =
sr$steepness,
        v = sr$vbiomass))
    dimnames(refpts(res))$refpt[5] = "crash"
    res = brp(res)
    if ("fbar" %in% names(args))
        fbar(res) <- args[["fbar"]]
    else fbar(res) <- FLQuant(seq(0, 1, length.out = 101)) *
        refpts(res)["crash", "harvest"]
    return(brp(res))
}
<environment: namespace:FLAdvice
```