BLACK SEA4FISH

PRESENTATION SERIES

Data limited stock assessment models-Three Monte-Carlo methods based on MonteCarlo approaches

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CNR IRBIM
ISTITUTO PER LE RISORSE BIOLOGICHE E LE BIOTECNOLOGIE MARINE

Food and Agriculture Organization of the United Nations

General Fisheries Commission for the Mediterranean
Commission générale des pêches pour la Méditerranée

FishBase

WoRMS
World Register of Marine Species

SeaLifeBase

School of Biology
Aristotle University of Thessaloniki

GEOMAR
Helmholtz Centre for Ocean Research Kiel

ISTI
Consiglio Nazionale delle Ricerche
ISTITUTO DI SCIENZA E TECNOLOGIE DELL'INFORMAZIONE "A. FAEDO"

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Research question:

How Monte Carlo approaches can be utilised in developing fish population dynamics models?

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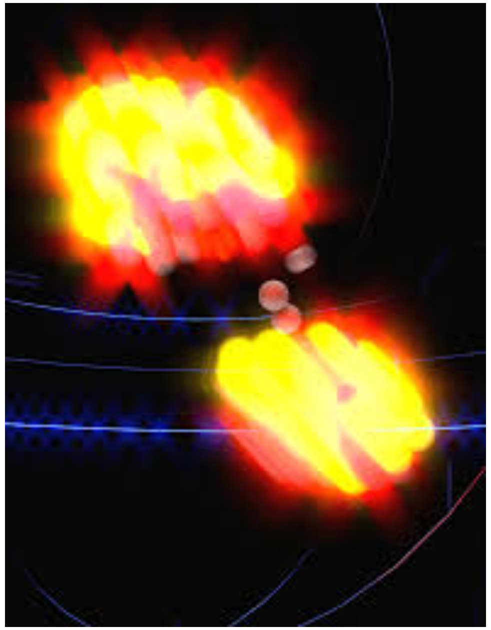
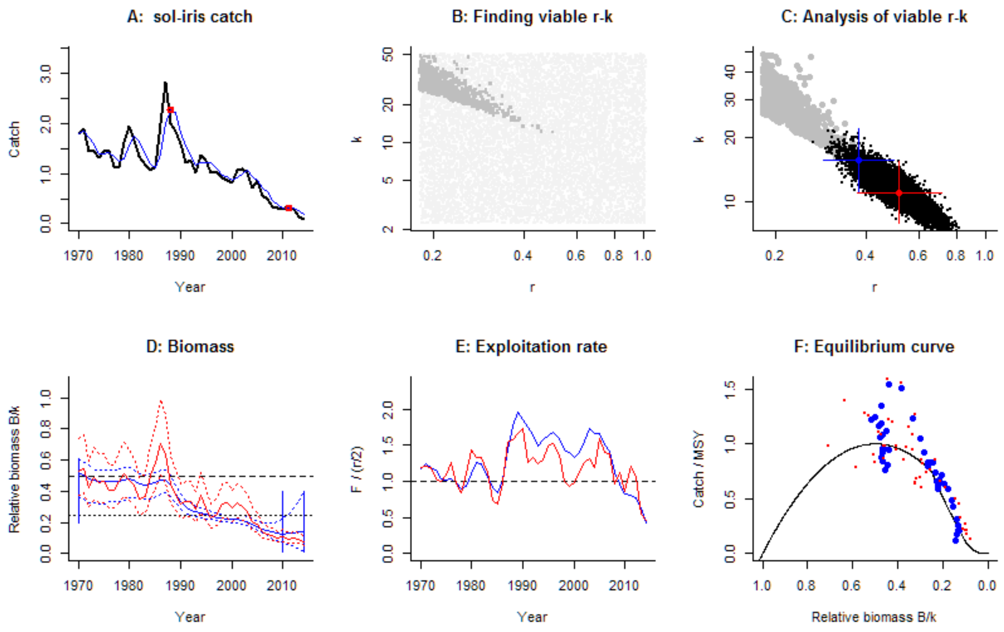
How Monte Carlo methods can be utilised in developing fish population dynamics models?

Monte Carlo simulation is, in essence, the generation of random objects or processes by means of a computer. These objects could arise ‘naturally’ as part of the modeling of a real-life system, such as a complex road network, the transport of neutrons, or…..





Methods used:

Monte Carlo methods are routinely used in stock assessment methodologies and accoding to data vailability it is possible to employ:

- Catch
  - Use **CMSY** (use expert interviews or better LBB for B/B_0 priors)
- Catch-per-unit-of-effort (CPUE)
  - Use **CMSY/BSM** if CPUE and catch data are available
  - Use **AMSY** if catch is unreliable or if true stock boundaries are unknown (use expert interviews or better LBB for B/B_0 prior anywhere in the time series)
- Length-frequencies from the commercial fishery
  - Use **LBB** (compare Linf with data in FishBase/SealifeBase)

The CMSY Method in a Nutshell

If CPUE is unknown, a prior range for *r* is derived from life history traits, a prior range for *k* is derived from maximum catch, and prior ranges for B_t/k (beginning and end of catch time series) are derived from expert knowledge or better from LBB.

$$B_{t+1} = B_t + r B_t \left(1 - \frac{B_t}{k}\right) - C_t$$

All *r-k* combinations that are compatible with the life history traits (*r, M, K*), the catches (C_t) and the expert knowledge (B_t/k) are identified by a Monte-Carlo approach. An *r-k* combination representative of high *r* values is chosen as best estimate.

The BSM Method in a Nutshell

Given a time series of Catch and CPUE, the parameters $r = r_{max}$ and $B_\infty = k$ are estimated from

$$B_{t+1} = B_t + r\,B_t \left(1 - \frac{B_t}{k}\right) - C_t$$

where C_t is catch in year t, $B = CPUE / q$, q is the catchability coefficient, and the other parameters are as defined above

Using a Bayesian approach, the *r-k* combination that minimizes the difference between the observed biomass and the one predicted by the equation is chosen as best estimate

FISH and FISHERIES

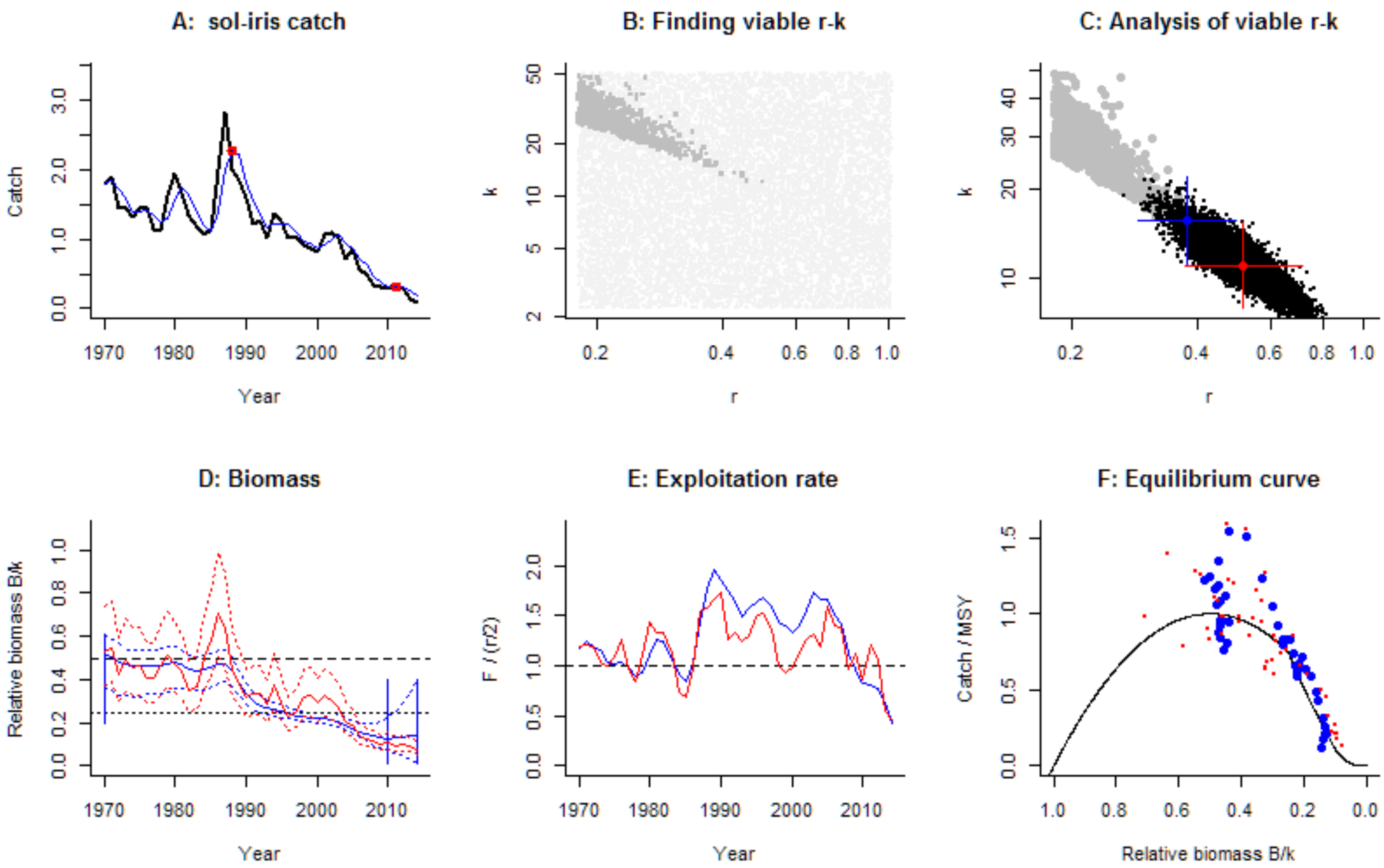
FISH and FISHERIES

Estimating fisheries reference points from catch and resilience

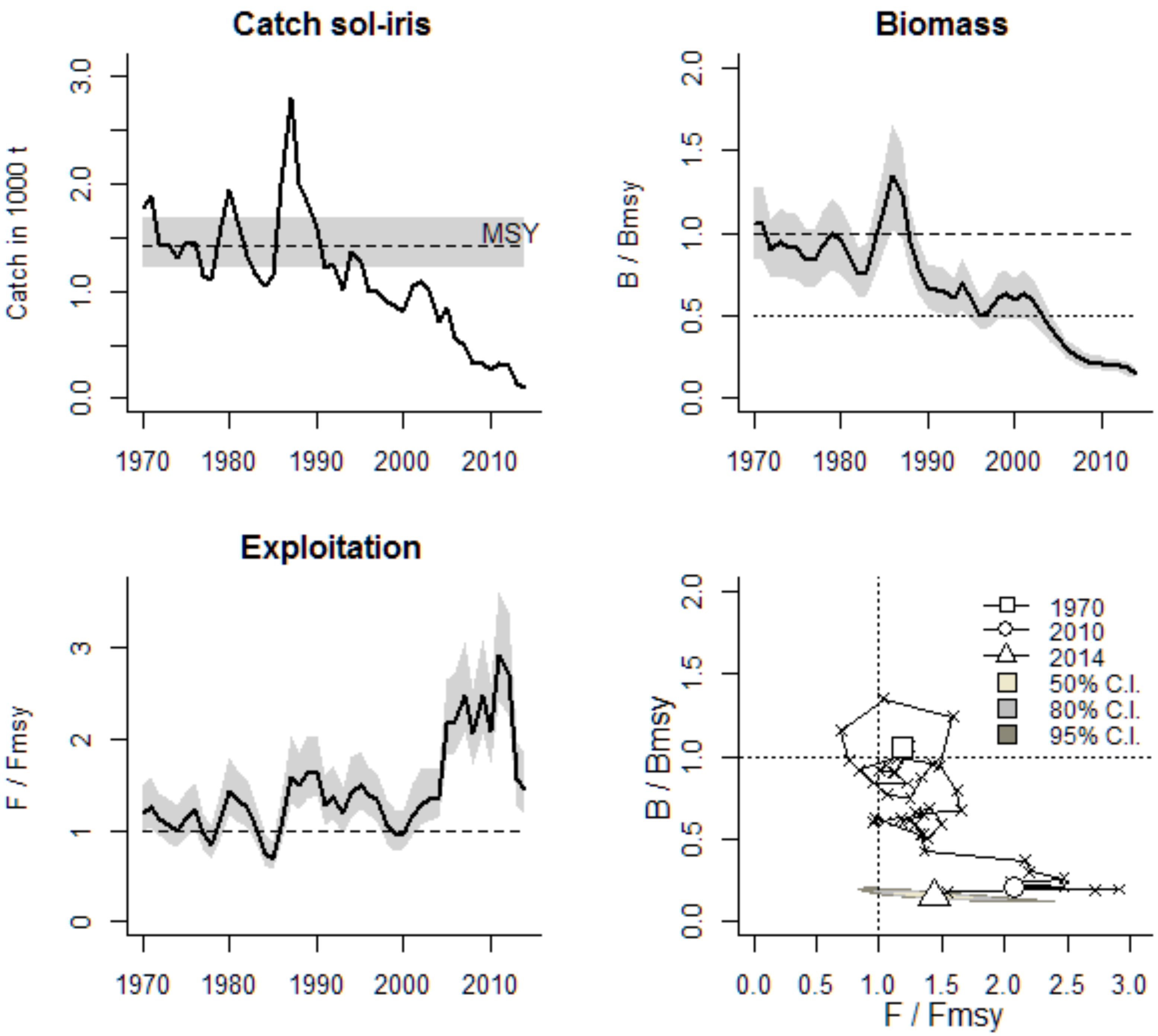
Rainer Froese[1], *Nazli Demirel*[2], *Gianpaolo Coro*[3], *Kristin M Kleisner*[4] & *Henning Winker*[5,6]

Abstract

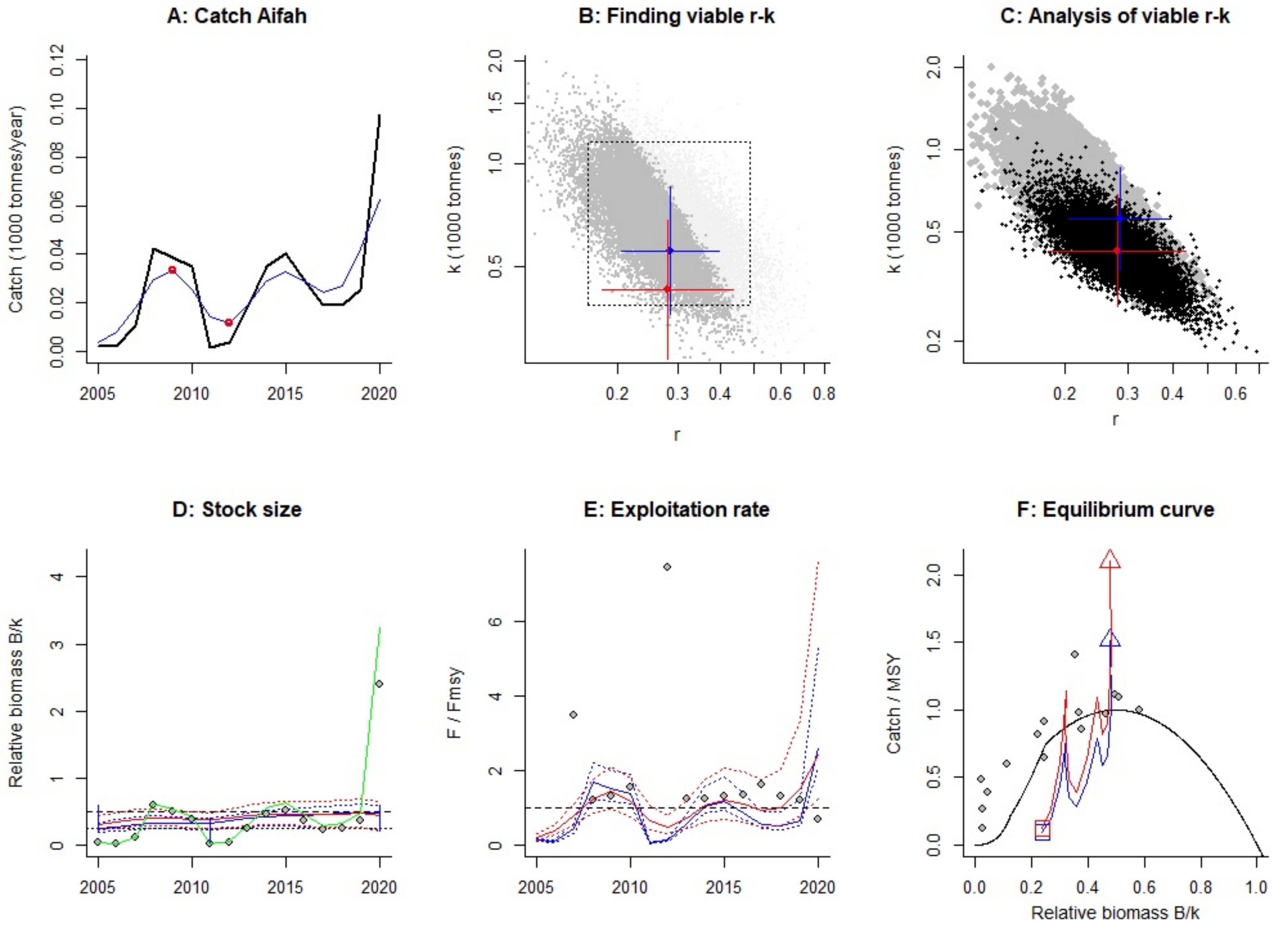
This study presents a Monte Carlo method (CMSY) for estimating fisheries reference points from catch, resilience and qualitative stock status information on data-limited stocks. It also presents a Bayesian state-space implementation of the Schaefer production model (BSM), fitted to catch and biomass or *catch-per-unit-of-effort* (*CPUE*) data. Special emphasis was given to derive informative priors for productivity, unexploited stock size, catchability and biomass from population dynamics theory. Both models gave good predictions of the maximum intrinsic rate of population increase *r*, unexploited stock size *k* and maximum sustainable yield *MSY* when validated against simulated data with known parameter values. CMSY provided, in addition, reasonable predictions of relative biomass and exploitation rate. Both models were evaluated against 128 real stocks, where estimates of biomass were available from full stock assessments. BSM estimates of *r*, *k* and *MSY* were used as benchmarks for the respective CMSY estimates and were not significantly different in 76% of the stocks. A similar test against 28 data-limited stocks, where *CPUE* instead of biomass was available, showed that BSM and CMSY estimates of *r*, *k* and *MSY* were not significantly different in 89% of the stocks. Both CMSY and BSM combine the production model with a simple stock–recruitment model, accounting for reduced recruitment at severely depleted stock sizes.

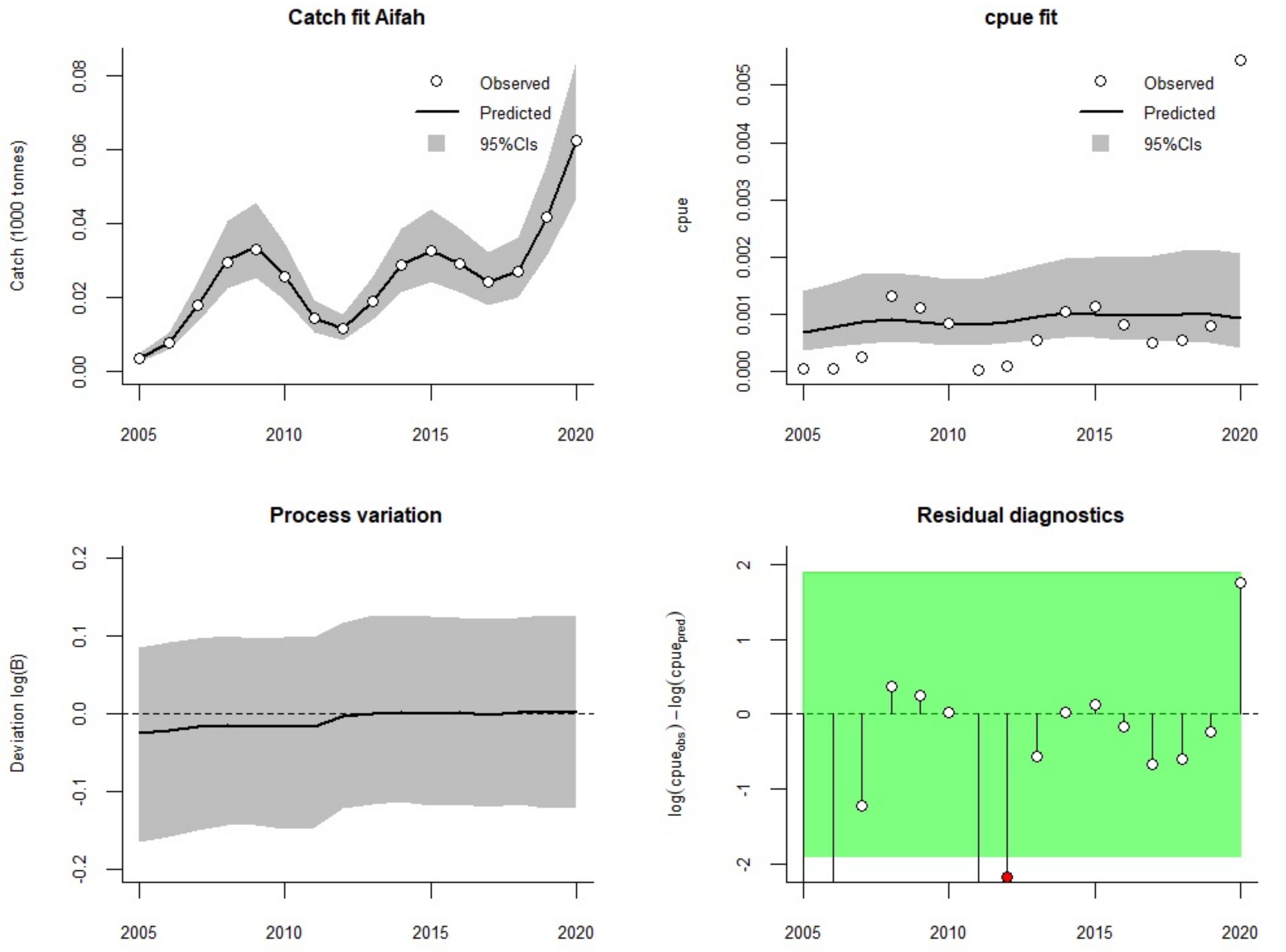


Sole in the Irish Sea: Graphic Results of CMSY/ BSM analysis for use by stock assessment working group

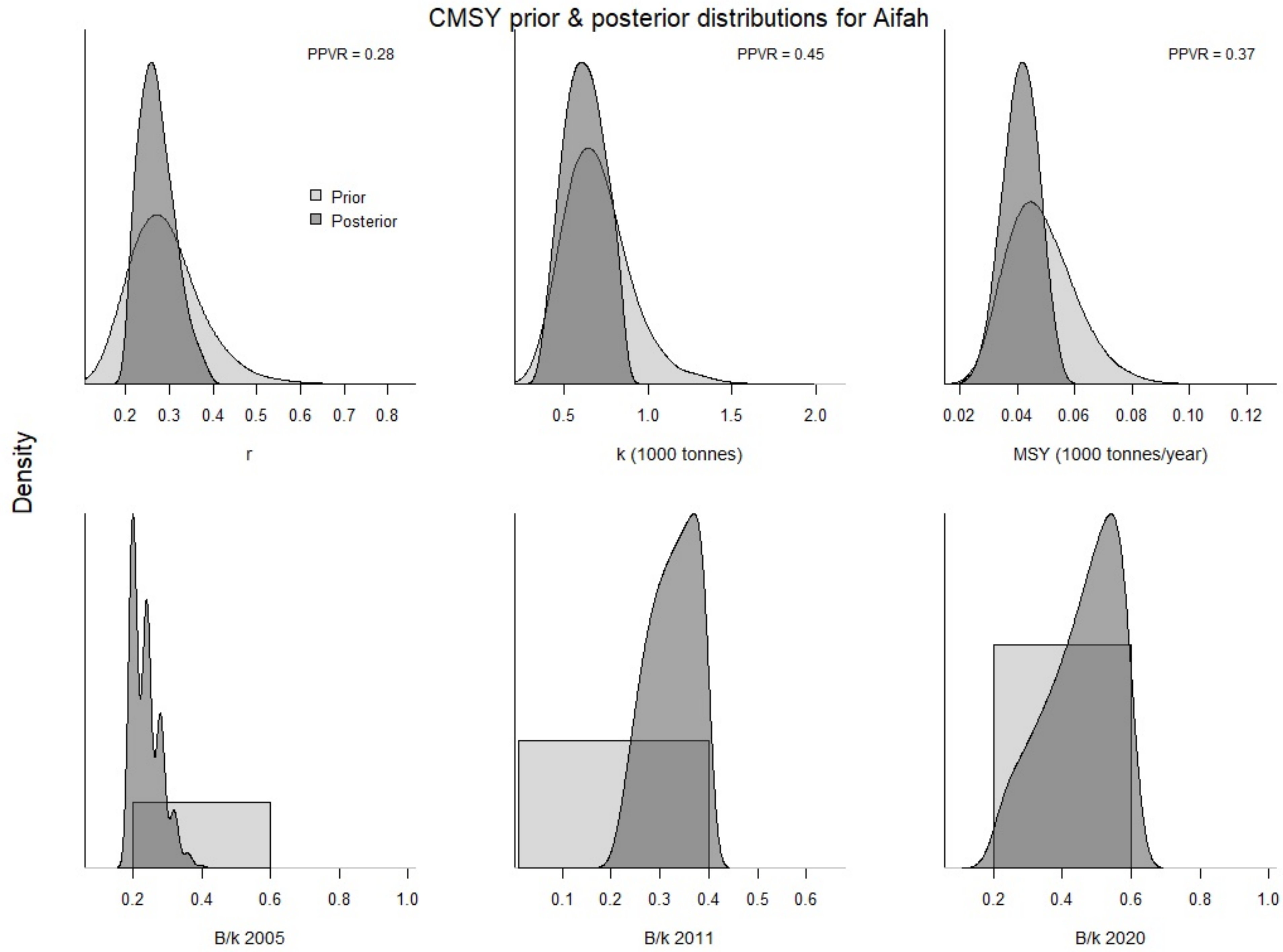


Sole in the Irish Sea:
Graphical results of
CMSY / BSM analysis
for use by management

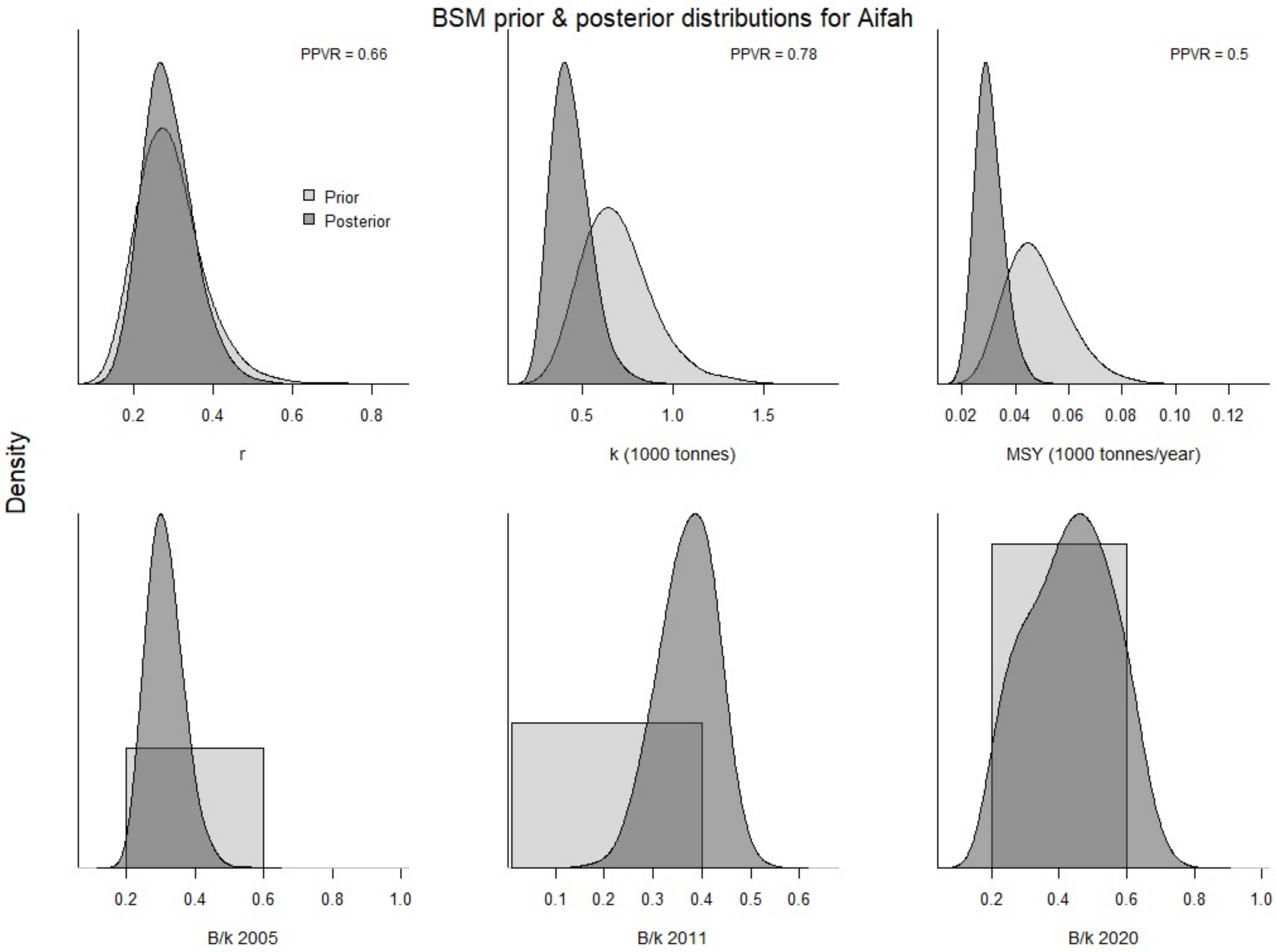

A: Catch Aifah
Catch (1000 tonnes/year)
B: Finding viable r-k
k (1000 tonnes)
r
C: Analysis of viable r-k
k (1000 tonnes)
r
D: Stock size
Relative biomass B/k
E: Exploitation rate
F / Fmsy
F: Equilibrium curve
Catch / MSY
Relative biomass B/k



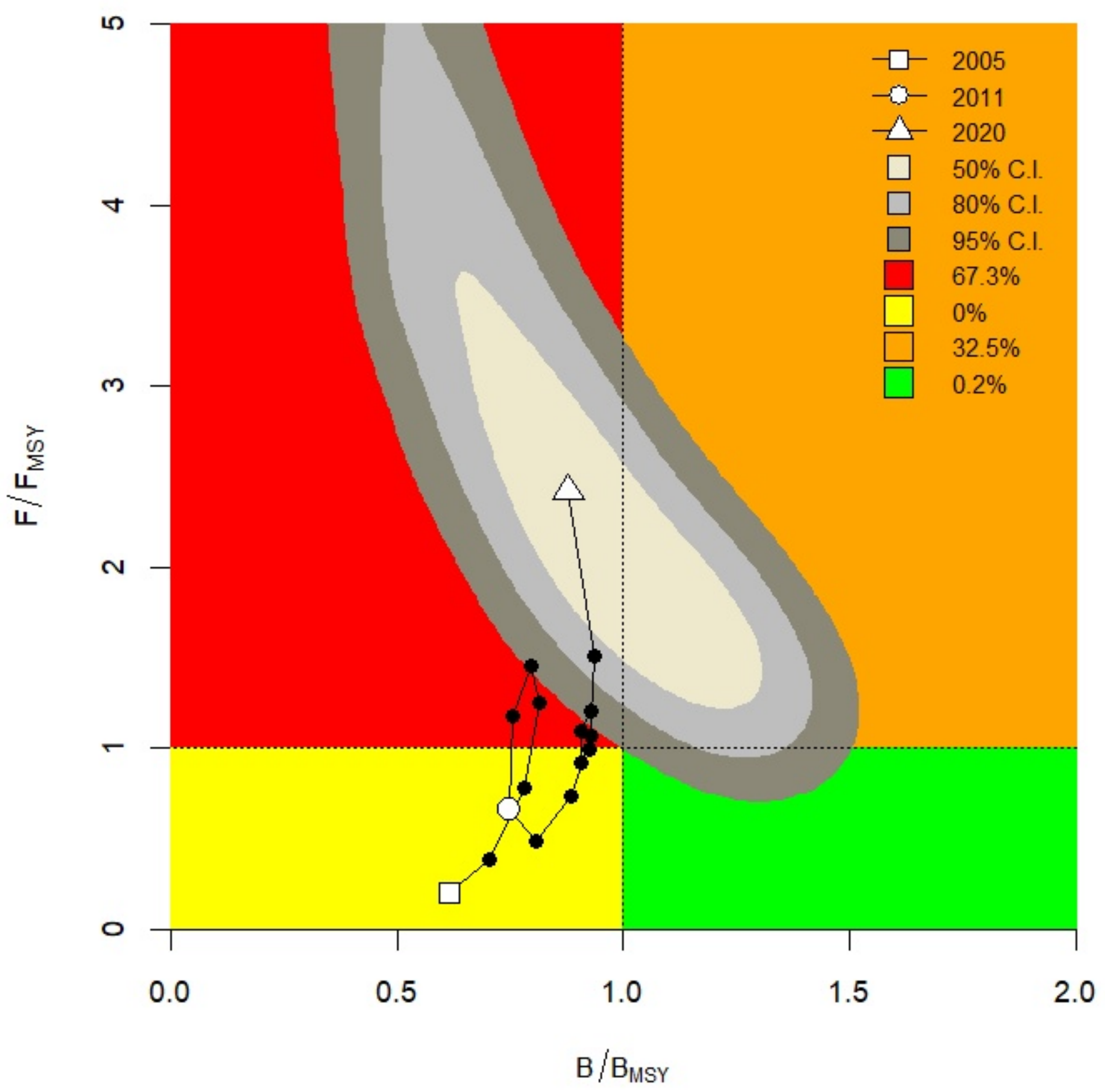
Catch fit Aifah
Observed
Predicted
95%CIs
Catch (1000 tonnes)
0.00
0.02
0.04
0.06
0.08
2005
2010
2015
2020
cpue fit
Observed
Predicted
95%CIs
cpue
0.000
0.001
0.002
0.003
0.004
0.005
Process variation
Deviation log(B)
-0.2
-0.1
0.0
0.1
0.2
Residual diagnostics
log(cpue_obs) - log(cpue_pred)
-2
-1
0
1
2

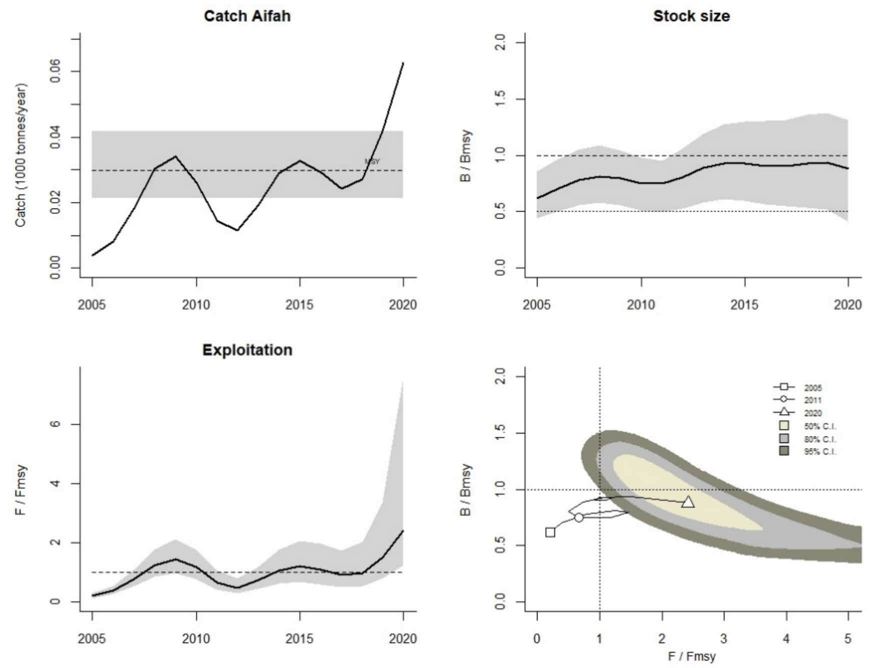


CMSY prior & posterior distributions for Aifah
Density
PPVR = 0.28
Prior
Posterior
0.2 0.3 0.4 0.5 0.6 0.7 0.8
r
PPVR = 0.45
0.5 1.0 1.5 2.0
k (1000 tonnes)
PPVR = 0.37
0.02 0.04 0.06 0.08 0.10 0.12
MSY (1000 tonnes/year)
0.2 0.4 0.6 0.8 1.0
B/k 2005
0.1 0.2 0.3 0.4 0.5 0.6
B/k 2011
0.2 0.4 0.6 0.8 1.0
B/k 2020

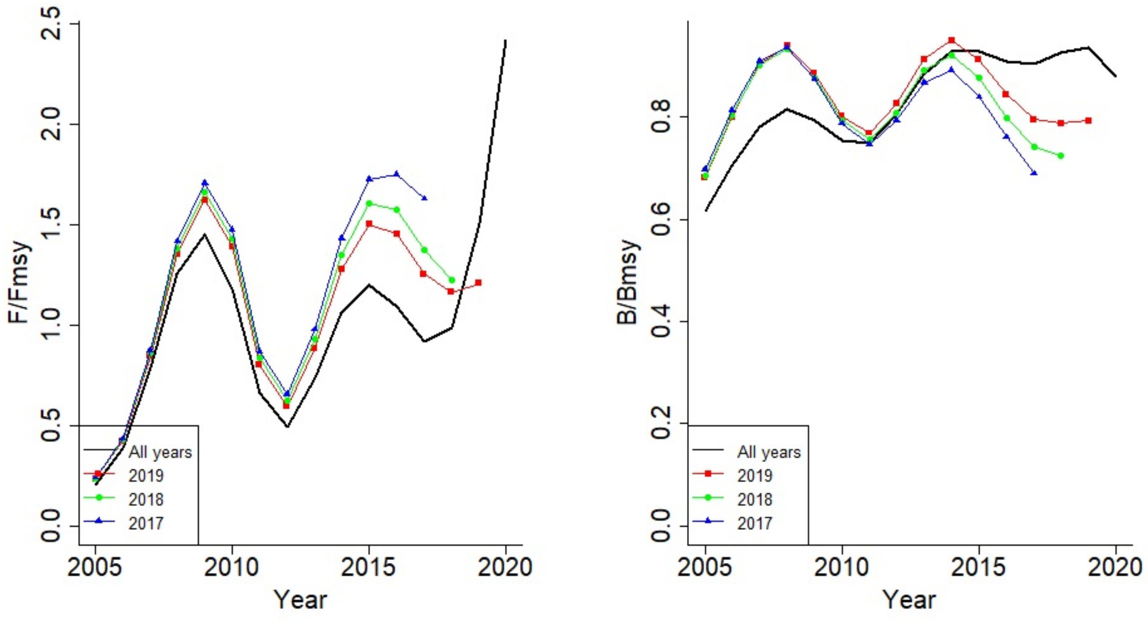


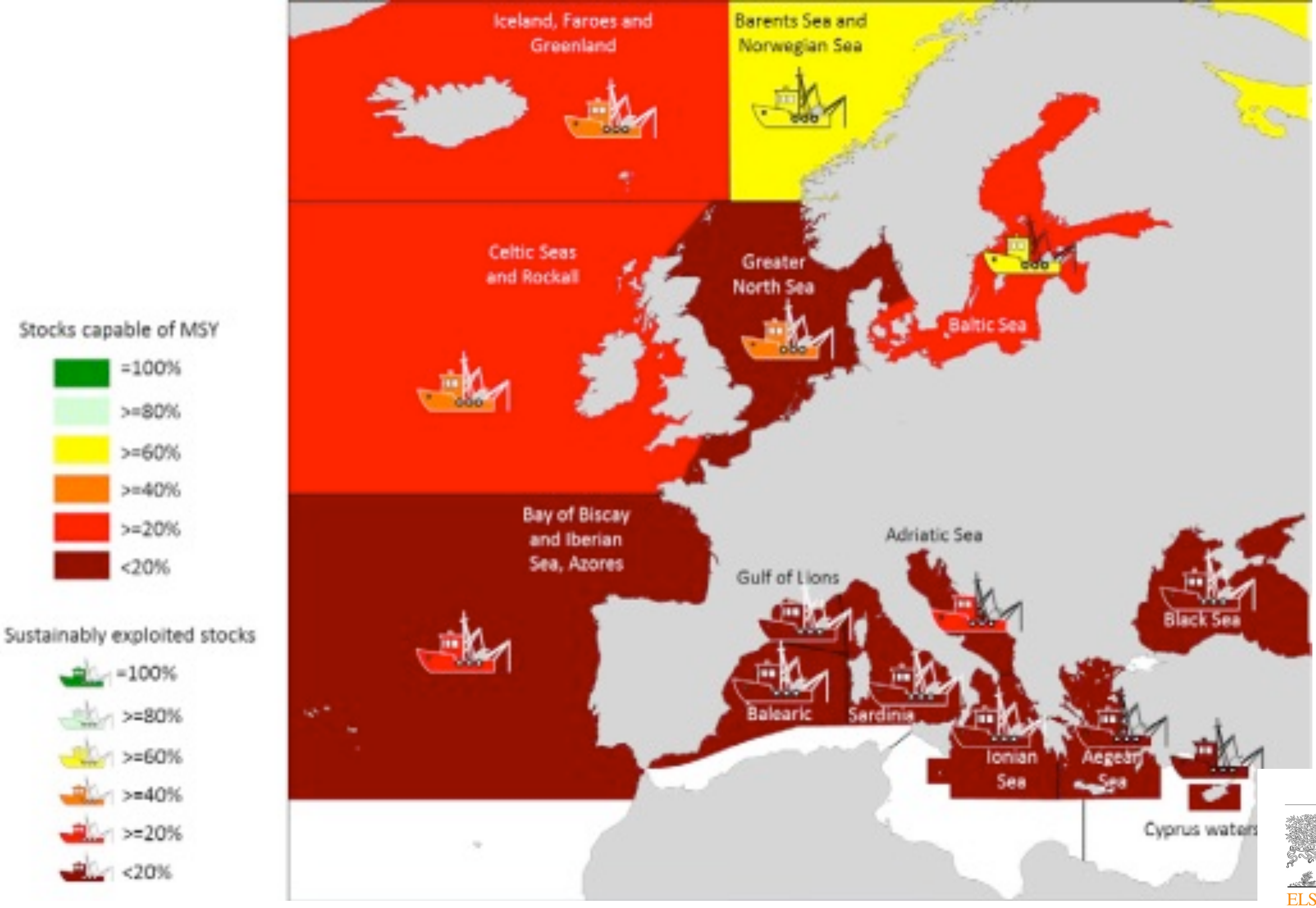
BSM prior & posterior distributions for Aifah
Density
PPVR = 0.66
Prior
Posterior
0.2
0.4
0.6
0.8
r
PPVR = 0.78
0.5
1.0
1.5
k (1000 tonnes)
PPVR = 0.5
0.02
0.04
0.06
0.08
0.10
0.12
MSY (1000 tonnes/year)
0.2
0.4
0.6
0.8
1.0
B/k 2005
0.1
0.2
0.3
0.4
0.5
0.6
B/k 2011
0.2
0.4
0.6
0.8
1.0
B/k 2020





Retrospective analysis for Aifah





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ELSEVIER

Status and rebuilding of European fisheries

Rainer Froese[a,*], Henning Winker[b,c], Gianpaolo Coro[d], Nazli Demirel[e], Athanassios C. Tsikliras[f,*], Donna Dimarchopoulou[f], Giuseppe Scarcella[g], Martin Quaas[h], Nele Matz-Lück[i]

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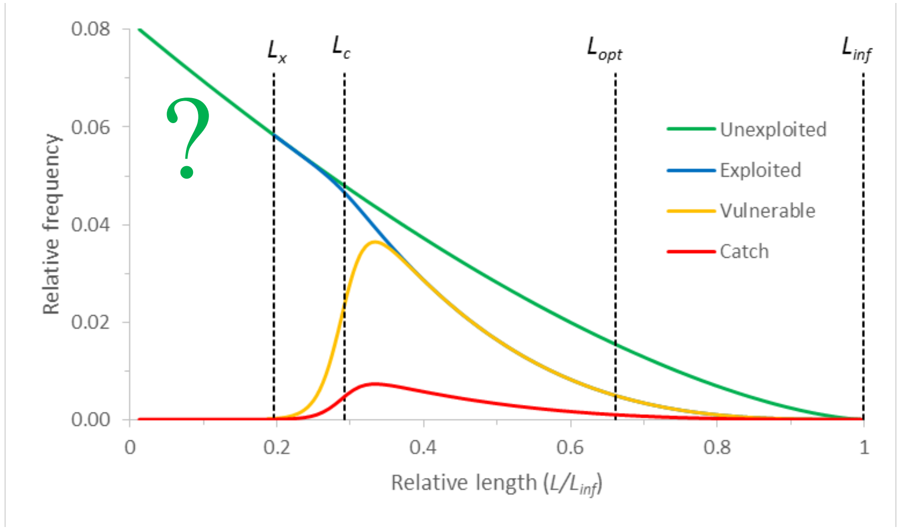
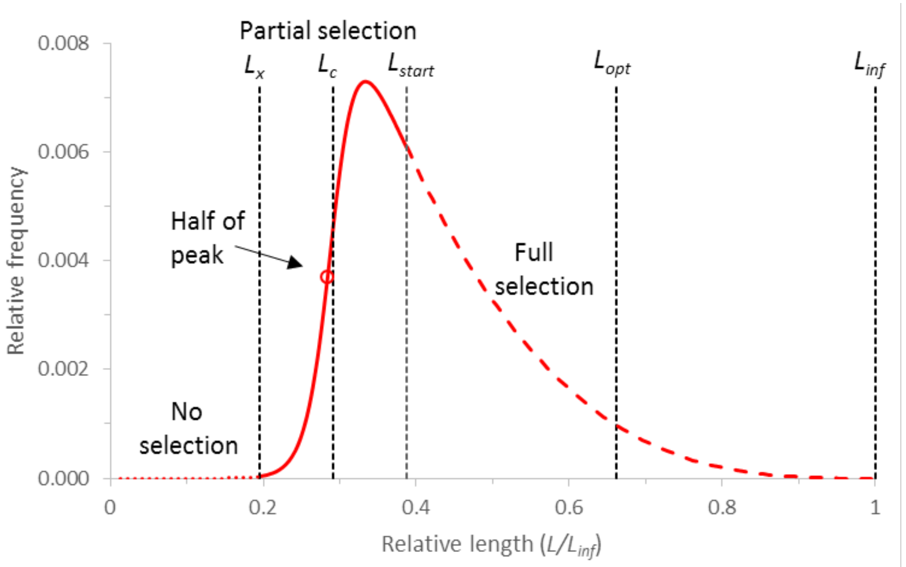
[h] Institute of Economics, Kiel University, Wilhem-Seelig-Platz 1, 24118 Kiel, Germany
[i] Walther Schücking Institute of International Law, Kiel University, Westring 400, 24118 Kiel, Germany

The LBB Method in a Nutshell



L_c	Length where 50% of the individuals are retained by the gear
L_{inf}	Asymptotic length of the von Bertalanffy growth equation
K	Growth rate of the von Bertalanffy growth equation
M	Natural mortality rate
F	Fishing mortality rate
N	Number of individuals
S_{Li}	Gear selectivity at length *i*
C_{Li}	Catch at length *i*



The LBB Equations

Gear-selectivity: $$S_{L_i} = \frac{1}{1 + e^{-\alpha(L_i - L_c)}}$$

Survivors to L_i: $$N_{L_i} = N_{L_{i-1}} \left(\frac{L_{inf} - L_i}{L_{inf} - L_{i-1}}\right)^{\frac{M}{K} + \frac{F}{K} S_{L_i}}$$

Vulnerable/ relative catch at L_i: $$C_{L_i} = N_{L_i} S_{L_i}$$

Using a Bayesian approach with priors derived from previous or aggregated LFs, all parameters are estimated simultaneously.

The LBB Equations

Gear-selectivity: $S_{L_i} = \frac{1}{1 + e^{-\alpha(L_i - L_c)}}$

Survivors to L_i: $N_{L_i} = N_{L_{i-1}} \left(\frac{L_{inf} - L_i}{L_{inf} - L_{i-1}} \right)^{\frac{M}{K} + \frac{F}{K} S_{L_i}}$

Vulnerable/
relative catch at L_i : $C_{L_i} = N_{L_i} S_{L_i}$

Using a Bayesian approach with priors derived from previous or aggregated LFs, all parameters are estimated simultaneously.

Performance of LBB

- LBB results for relative biomass or stock status have been validated against simulations and against real stocks
- LBB predictions were not significantly different from the “true“ B/B_0 values of the simulations
- LBB predictions for stock status were similar to those obtained from full stock assessments

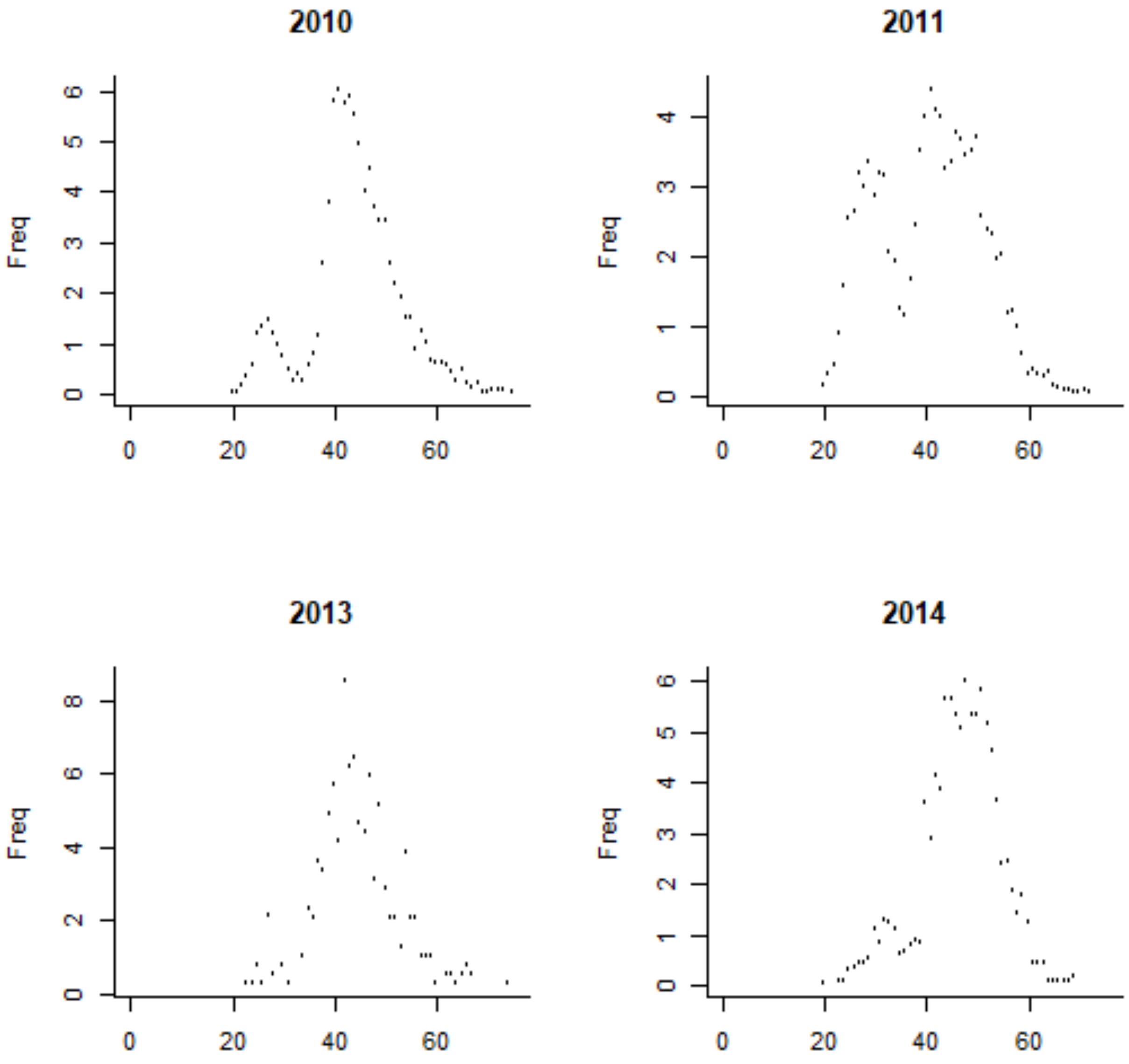
ICES Journal of Marine Science

ICES Journal of Marine Science (2018), doi:10.1093/icesjms/fsy078

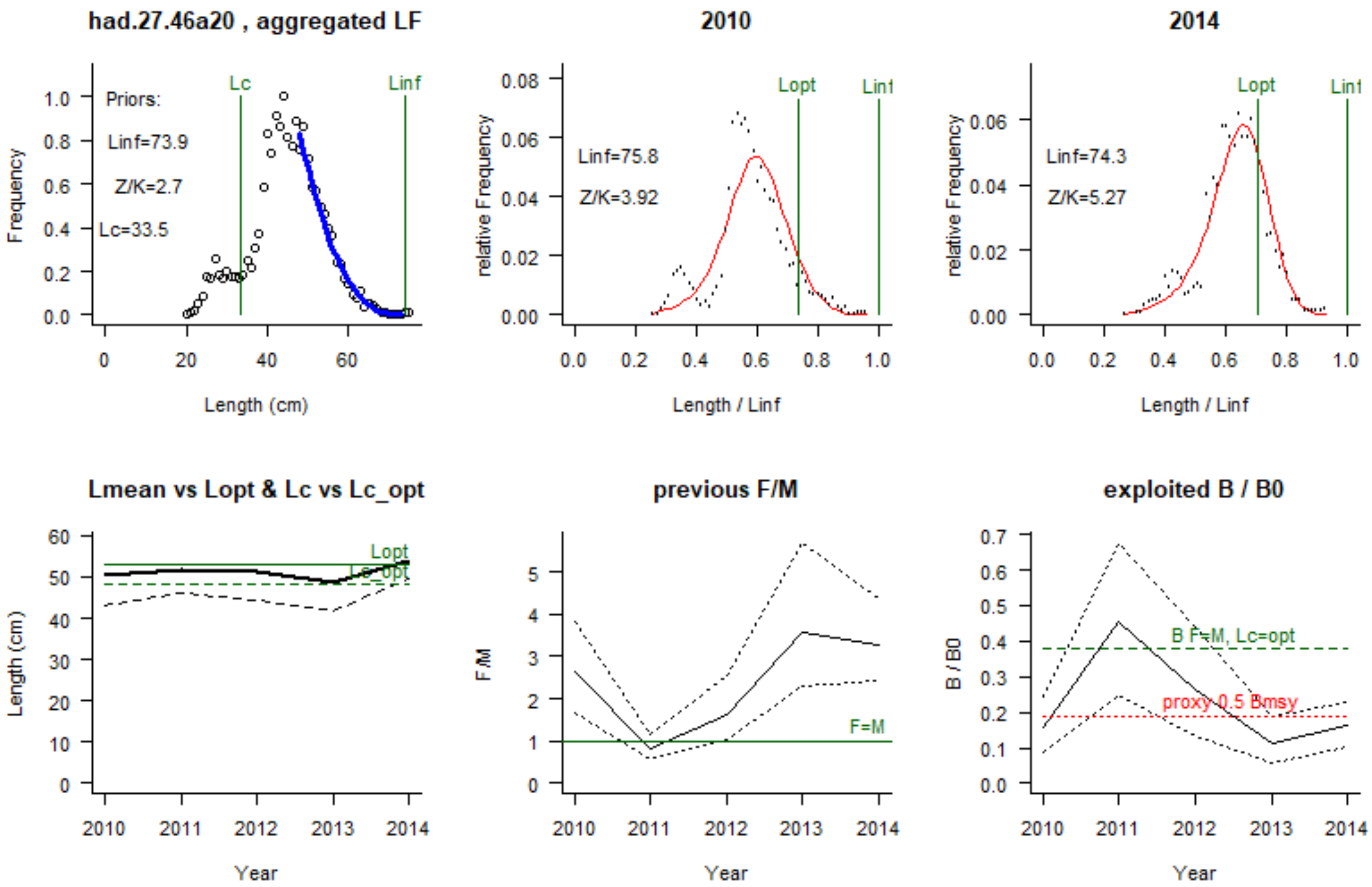
A new approach for estimating stock status from length frequency data

Rainer Froese[1,*], Henning Winker[2,3], Gianpaolo Coro[4], Nazli Demirel[5], Athanassios C. Tsikliras[6], Donna Dimarchopoulou[6], Giuseppe Scarcella[7], Wolfgang Nikolaus Probst[8], Manuel Dureuil[9,10], and Daniel Pauly[11]

Example for Haddock in the North Sea



Example for Haddock in the North Sea



LBB gives:
F/M=3.2
B/B0=0.16
B/Bmsy=0.43

ICES:
F/Fmsy=1.6
SSB/Bmsy=0.69
(Bmsy~2*Bpa)

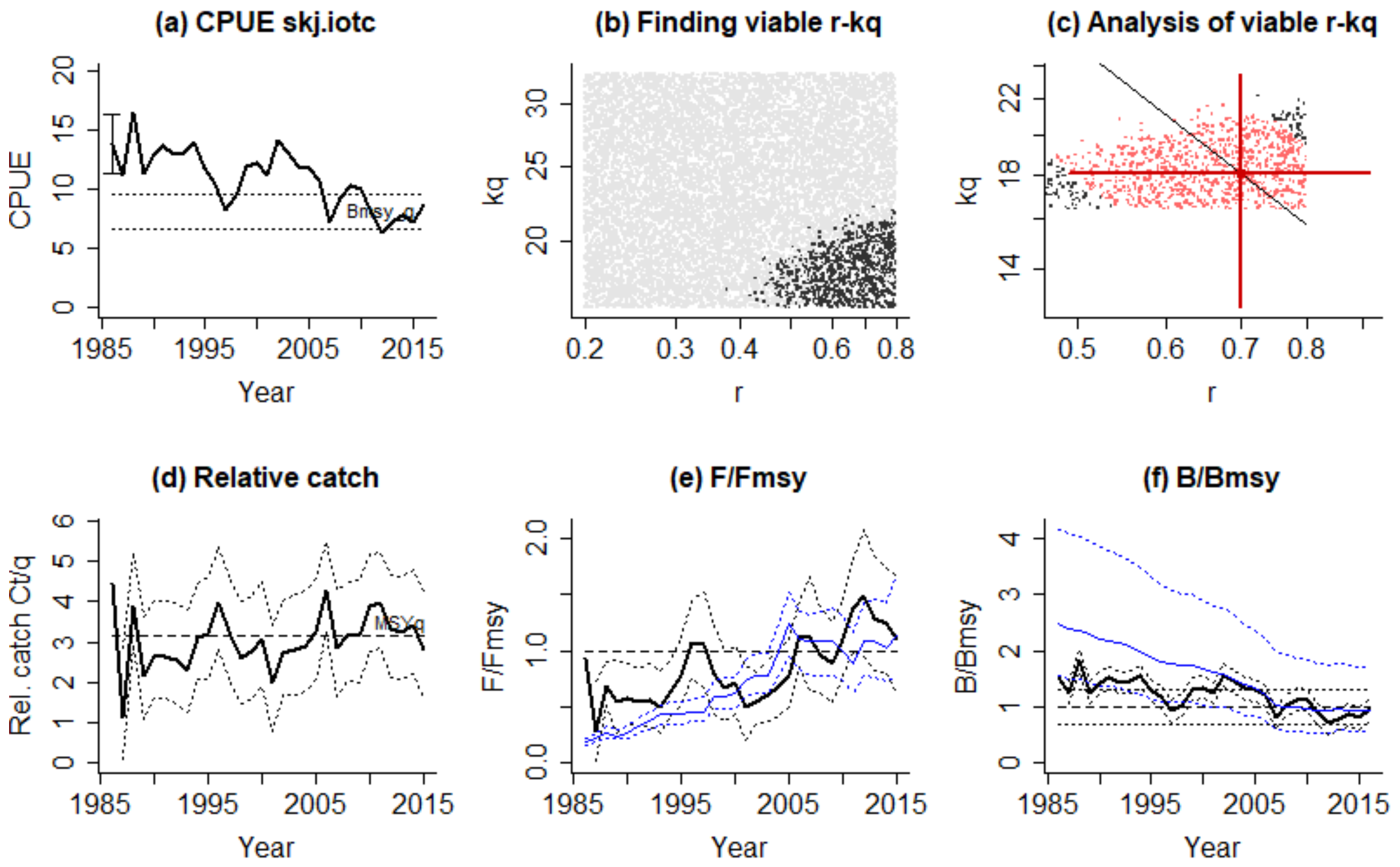
The AMSY Method in a Nutshell

If only CPUE is known, a prior range for *r* is derived from FishBase, a single prior range for *B*/*k* = CPUE/kq (anywhere in the time series) is derived from expert knowledge or better from LBB. The lower end of the range must be larger than max CPUE.

$$CPUE_{t+1} = CPUE_t + r\, CPUE_t \left(1 - \frac{CPUE_t}{k_q}\right) - C_{q\,t}$$

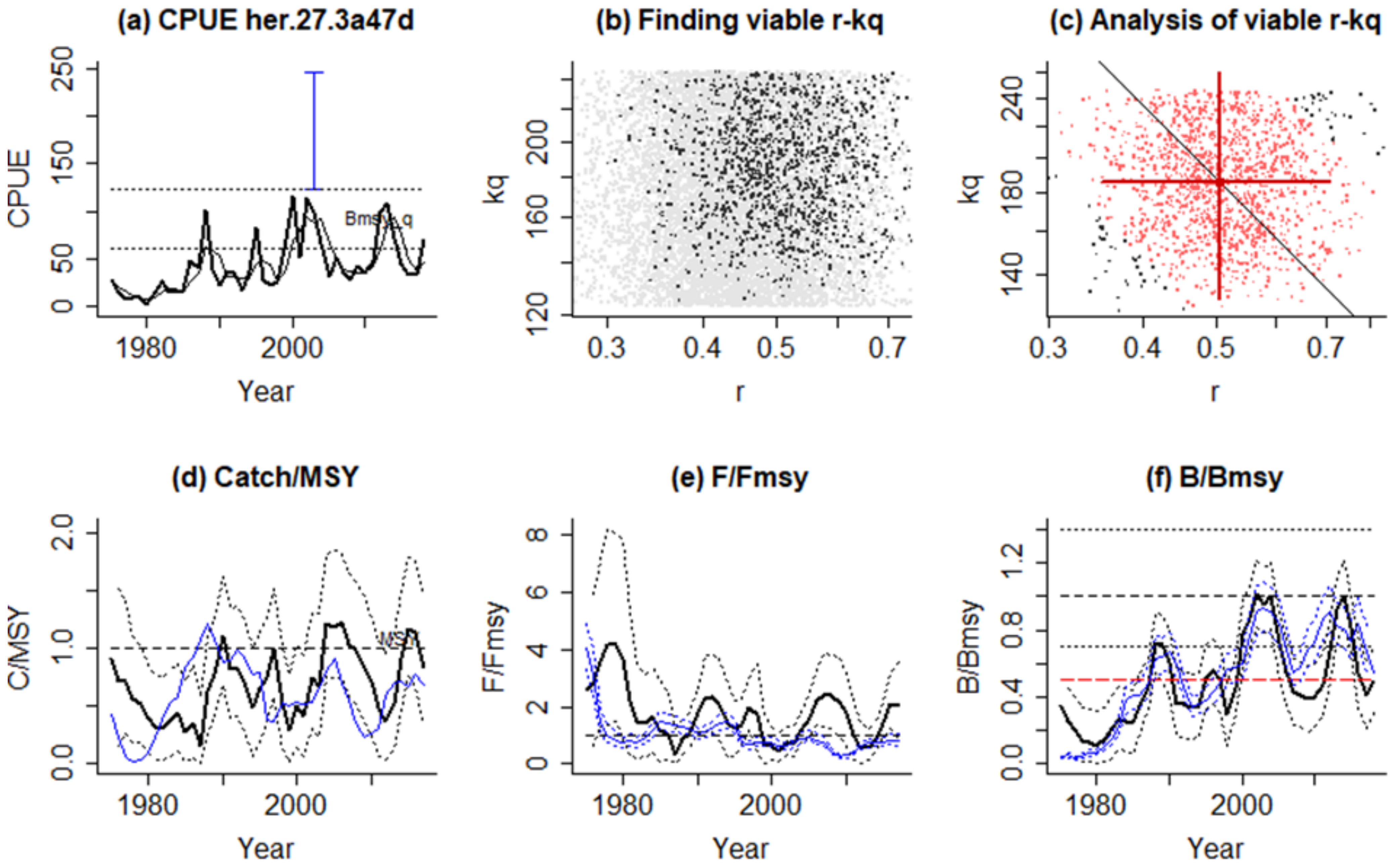
All r-k_q combinations that are compatible with the CPUE in the sense that they result in time series of plausible (never negative, never much too high) predicted catches are identified by a Monte-Carlo approach.

AMSY assessment of Skipjack tuna in the Indian Ocean

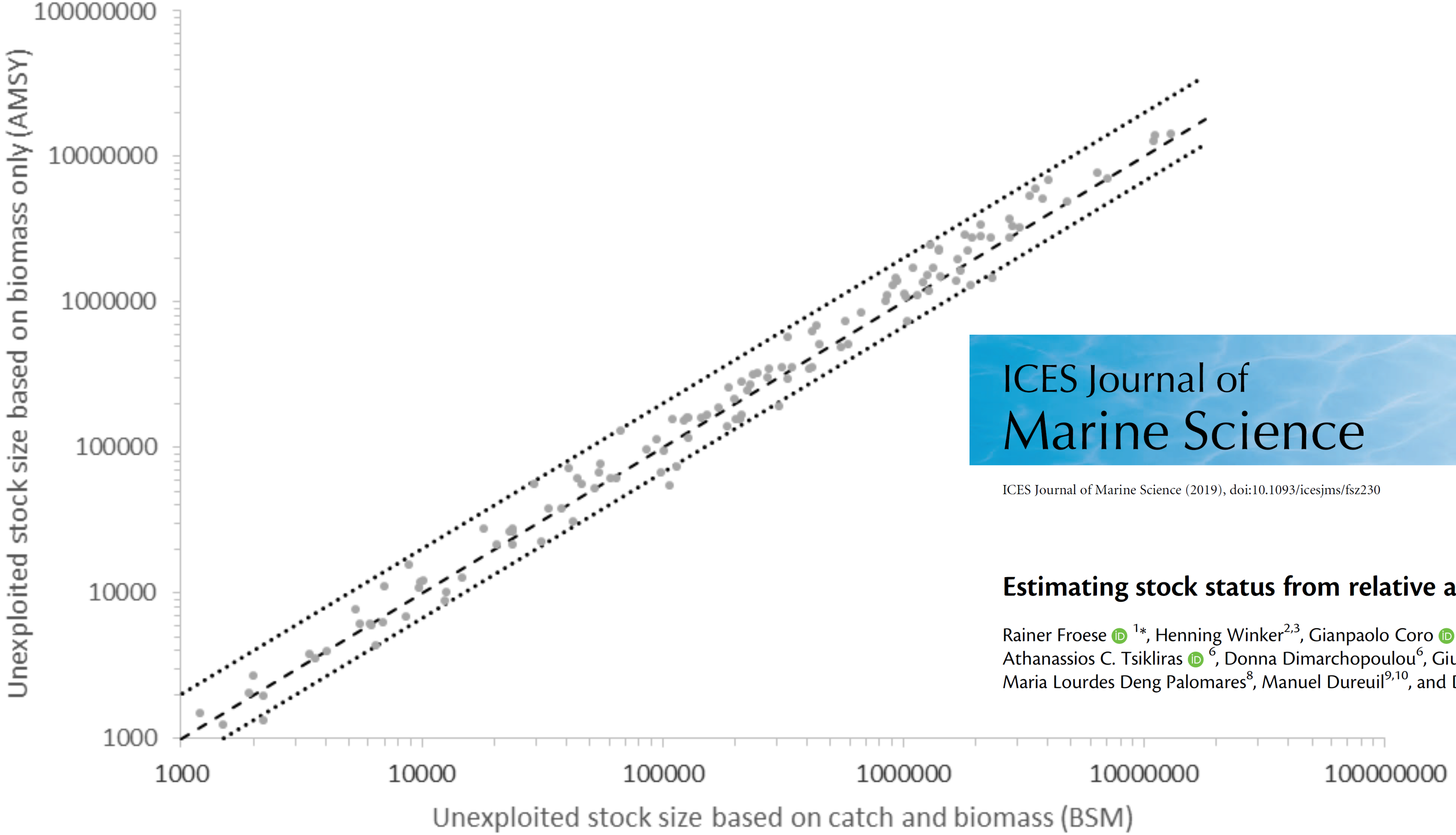


Consider “effort creep” in commercial CPUE

- Fisher tend to follow the stock and can maintain high catches even if the overall stock is declining
- Because of increasing experience of fishers or better gears or better equipment, the catch per effort tends to increase
- CMSY and AMSY allow to correct for effort increase
- 2% per year has been found to be a reasonable average in many fisheries (Pauly and Palomares, submitted)


(a) CPUE her.27.3a47d
CPUE
Year
Bmsy x q
(b) Finding viable r-kq
kq
r
(c) Analysis of viable r-kq
kq
r
(d) Catch/MSY
C/MSY
Year
MSY
(e) F/Fmsy
F/Fmsy
Year
(f) B/Bmsy
B/Bmsy
Year

Comparison with full Schaefer



ICES Journal of Marine Science
ICES CIEM
International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

ICES Journal of Marine Science (2019), doi:10.1093/icesjms/fsz230

Estimating stock status from relative abundance and resilience

Rainer Froese [1]*, Henning Winker[2,3], Gianpaolo Coro [4], Nazli Demirel [5], Athanassios C. Tsikliras [6], Donna Dimarchopoulou[6], Giuseppe Scarcella[7], Maria Lourdes Deng Palomares[8], Manuel Dureuil[9,10], and Daniel Pauly [8]

Summarizing:

Monte Carlo methods are routinely used in stock assessment methodologies and accoding to data availability it is possible to employ:

- Length-frequencies from the commercial fishery
  - Use **LBB** (compare Linf with data in FishBase/SealifeBase)
- Catch
  - Use **CMSY** (use expert interviews or better LBB for B/B_0 priors)
- Catch-per-unit-of-effort (CPUE)
  - Use **CMSY/BSM** if CPUE and catch data are available
  - Use **AMSY** if catch is unreliable or if true stock boundaries are unknown (use expert interviews or better LBB for B/B_0 prior anywhere in the time series)

Results implication

The MCM continues to be one of the most useful approaches to scientific computing due to its simplicity and general applicability als oin stock assessment.

- CMSY/BSM evaluated against 128 real stocks, where estimates of biomass were available from full stock assessments, showed a pretty good agreement (76%)
- LBB gives preliminary estimates of stock status based on length frequency data from the fishery
- AMSY seems to be well suited for estimating productivity r and thus Fmsy = ½ r as well as relative stock size B/k or B/Bmsy. The combination of AMSY with objective relative biomass (B/B0) priors derived from LBB appears to be a promising approach to produce MSY-level stock assessments for the many commercially caught species that lack reliable catch data.