

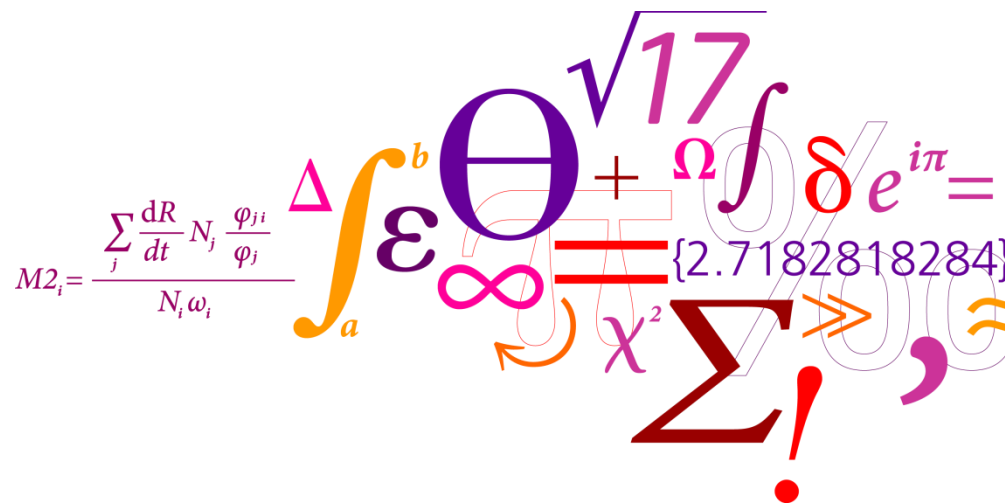
SMS – the Stochastic Multi-Species model

The HTL model in OpEc/Baltic

Stefan Neuenfelt, Asbjørn Christensen, Morten Vinther

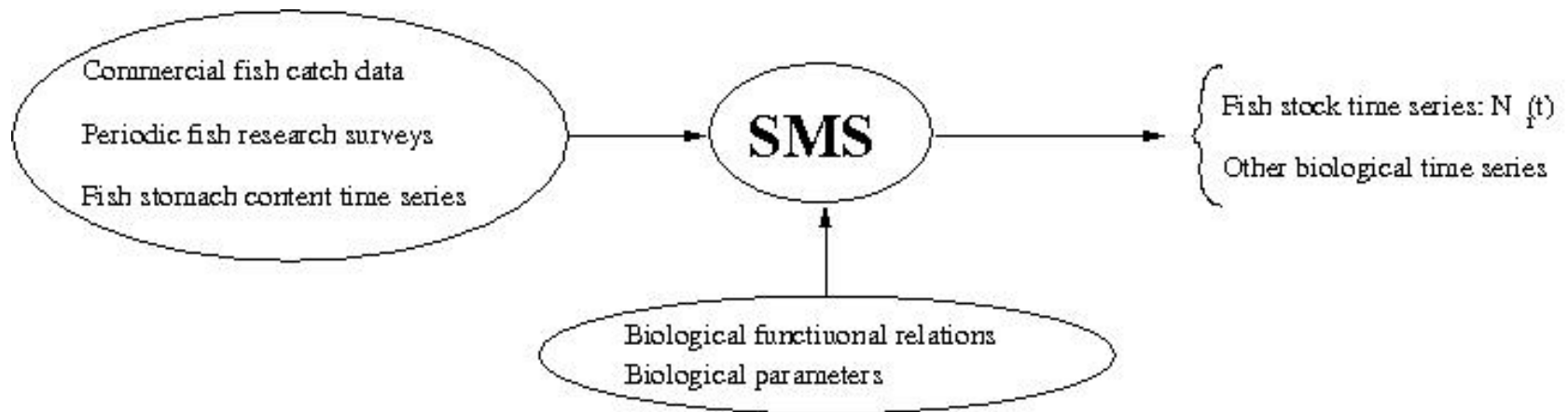
DTU Aqua

OpEc - Darlington - Dec 11, 2012



What is the SMS model ?

- Natively HTL analysis model – not a simulation model ...
- Application proven data-oriented model for assessing multiple fish stock time series



Strengths of the SMS model:

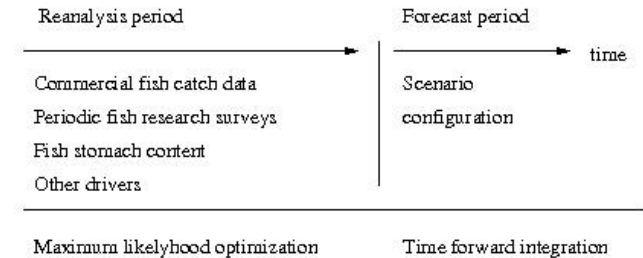
- Advanced trophic interactions
- Management strategy evaluation setup available

SMS: basis and main structure

1. SMS model is an analysis model rather than simulation model:
 - Robust toward observations with errors/bias
 - Results with confidence limits
2. Process-oriented knowledge enters via e.g. many sized-based functional relations:
 - Stock cohort tracing: $N_{s,y+1} = N_{s,y} * e^{-Z_{s,y}}$
 - $Z = F + M1 + M2$
 - F = fishing mortality
 - $M2$ = predation mortality from model species, formulation based on Andersen and Ursin, 1977
 - $M1$ = residual mortality (input)

Statistical estimation in SMS

Operation mode:



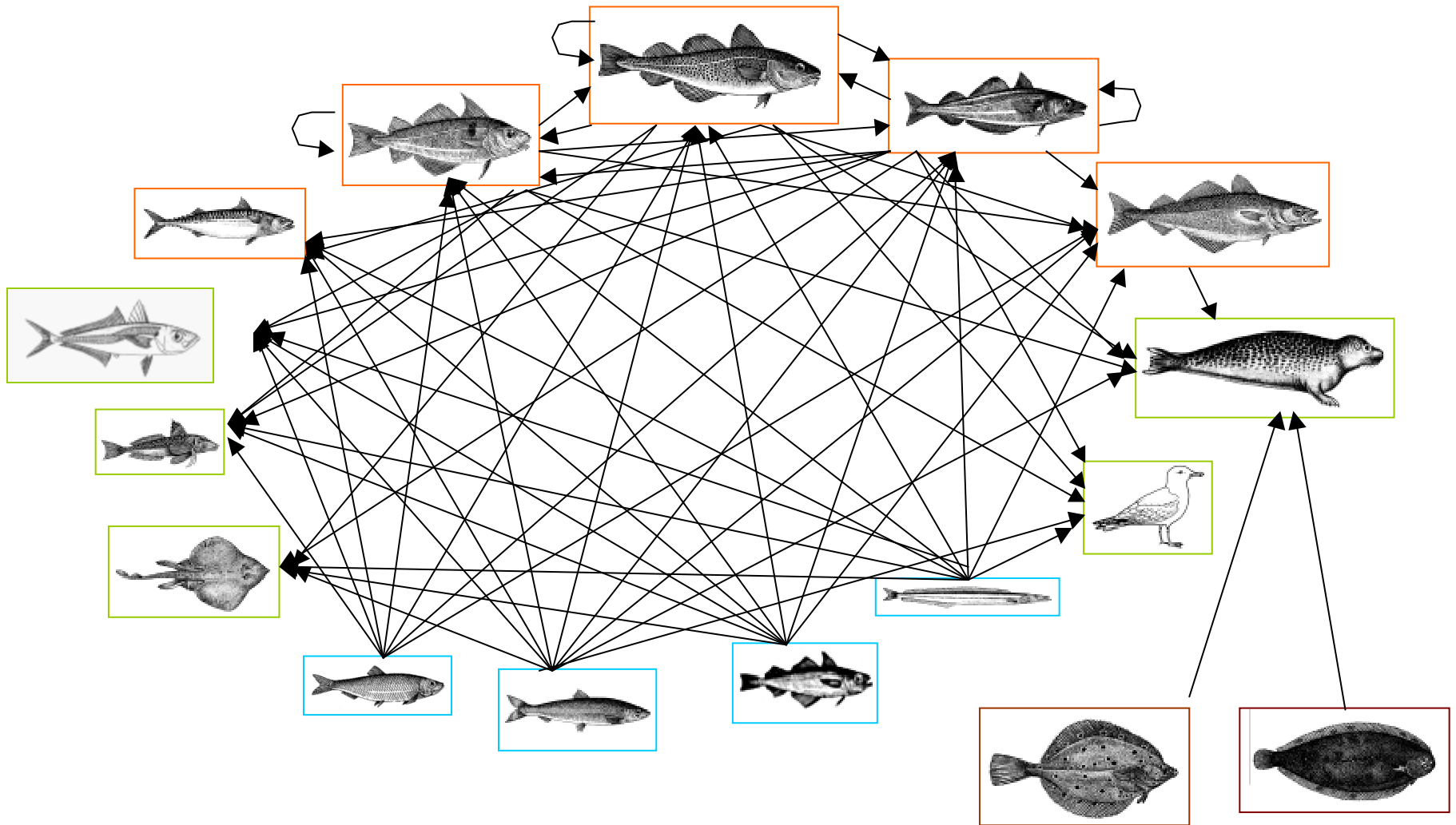
- Simulation models: $dN/dt = \dots$
- Maximum likelihood (L) estimation:

$L = \text{Probability}(\text{biological parameters} \mid \text{observations})$

$$\frac{\partial L}{\partial \text{Biological parameters}} = 0 \Rightarrow \text{biological parameters} = \dots$$

- $L = L_C * L_{\text{survey}} * L_{\text{STOM}} * L_{\text{S-R}}$
- L_C : Catch observation to fit F model
- L_{survey} : Survey observations to fit
CPUE = $\bar{N} * \text{catchability}$
- L_{STOM} : Stomach contents observation to fit M2 model
- $L_{\text{S-R}}$: Stock recruitment (penalty) function

Upper trophic interactions in the North Sea

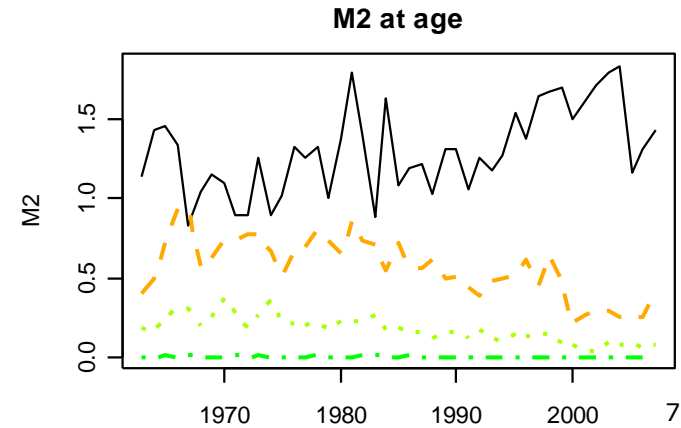
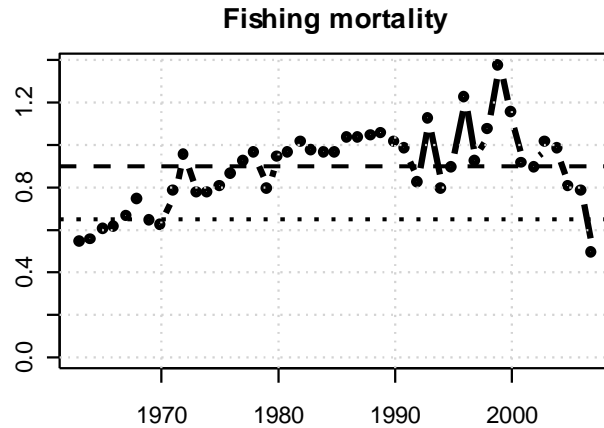
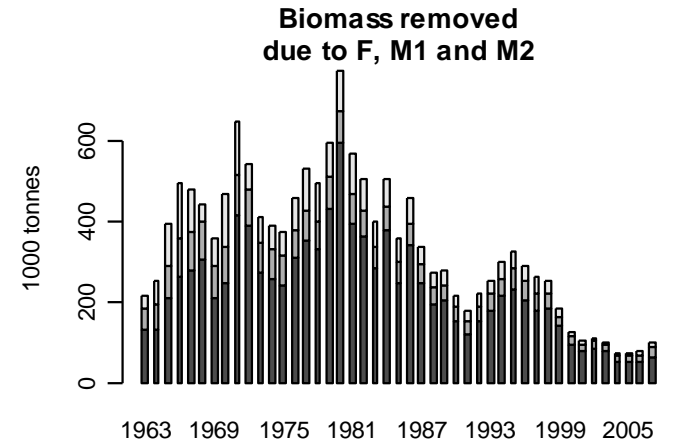
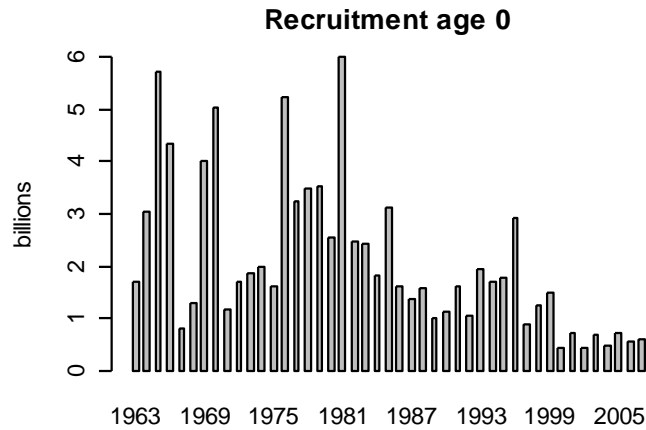
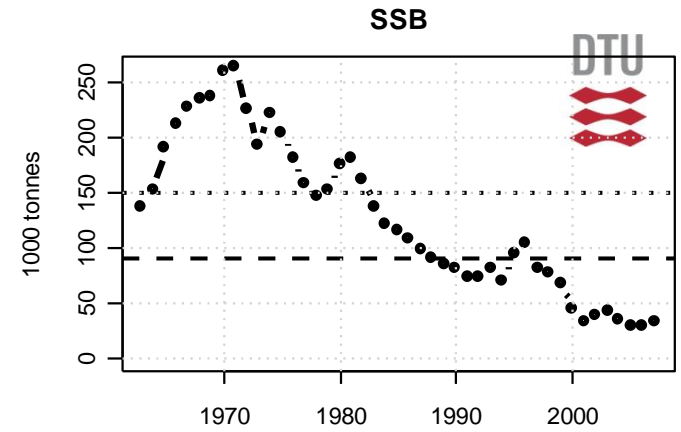
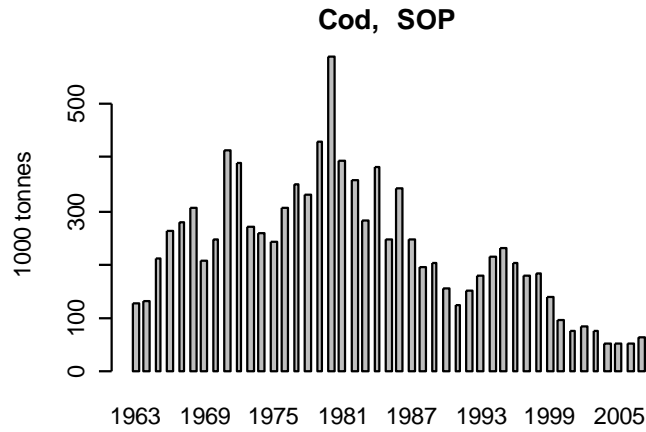


Stomach contents Likelihood

- Crown jewel of the SMS model: SMS will fit complex predator-prey interactions to extensive fish stomach content database
- Number of fish stomachs in North Sea database

Species	1981	1985	1986	1987	1990	1991	All
Cod	11,333	5,265	6,697	6,297	-	9,706	39,298
Haddock	17,241	-	-	-	-	12,893	30,134
North Sea mackerel	3,875	-	-	-	-	6,108	9,983
Saithe	3,420	-	2,102	967	-	3,219	9,708
Whiting	18,908	12,954	14,640	13,909	-	38,404	98,815
Grey Gurnard	-	-	-	-	1,082	11,717	12,799
Horse mackerel	-	-	-	-	-	3,189	3,189
Raja radiata	-	-	-	-	-	3,333	3,333
West mackerel	1,761	-	-	-	-	3,941	5,702
All	56,538	18,219	23,439	21,173	1,082	92,510	212,961

Example: SMS output North Sea cod

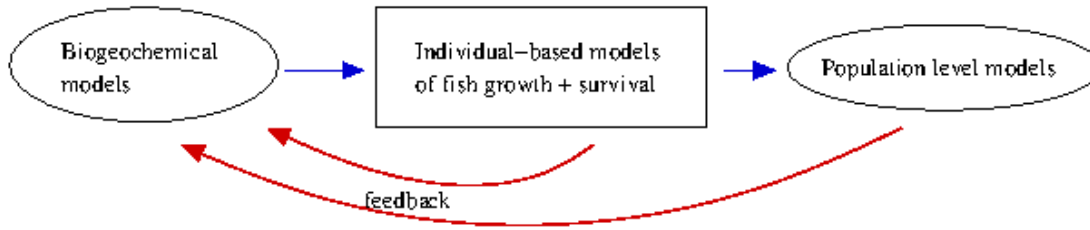


Implementation

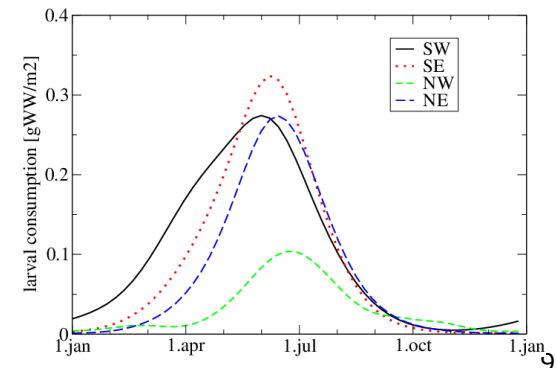
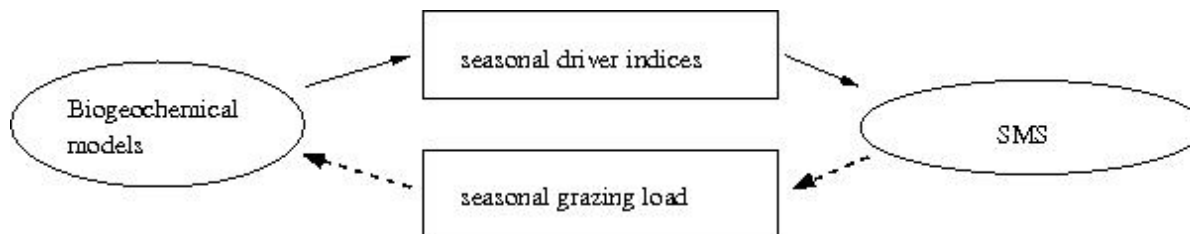
- Programmed in AD Model Builder
 - tool for developing and fitting non linear statistical models using Automatic Differentiation
 - Open source, freely available from <http://admb-foundation.org>
- North Sea configuration ~ 1000 parameters
 - ~ 50 “multi species” parameters
- Baltic Sea configuration ~ 350 parameters
 - ~10 “multi species” parameters
- Running time (Baltic Sea example), including variance estimate, less than 5 minutes on an up to date PC

The SMS model in E2E modelling

MEECE vision:



- SMS has limited spatiality (In OpEc 2-3 regions in the Baltic)
- Time scale mismatch: SMS time step = ¼ - 1 year
- Wide and deep knowlegde gaps for physical-biological interactions for many species and life stages
- Realistic procedure: index coupling:



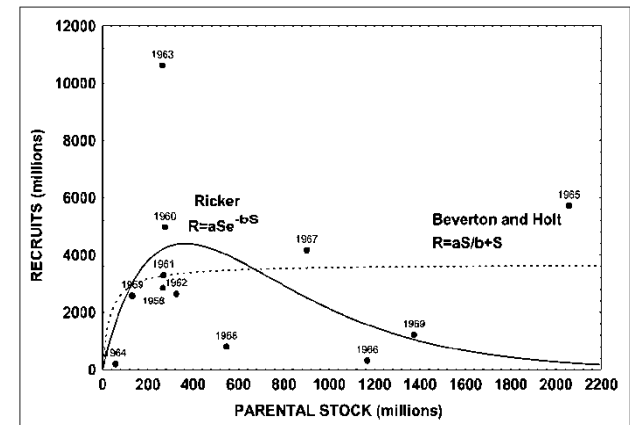
Progresses in OpEc

- A new forecast module has been added: allows hindcast runs in, addition to analysis, providing basis for D2.5
- Subregional ($n > 1$) setup for the Baltic HTL
- The physical-biological bottom-up interface to HRB has been implemented in IBMlib:
 - Allows efficient + flexible calculation of bottom-up coupling indices
 - Allows to compute recruitment potential indices by individual-based models (extending MEECE work)
- HTL development in OpEc @ DTU Aqua:
 - SMS development: Stefan Neuenfelt/Morten Vinther
 - Coupling to LTL: Asbjørn Christensen

Coupling SMS by bottum-up indices

- Simple hydrographic/biogeochemical indices has been tested in the Baltic (Lindegren et al, 2009):

Indices
Quarterly+regional stratified temperature average
Quarterly+regional stratified salinity average
Quarterly+regional stratified zooplankton average
Yearly cod reproductive volume



Link process	method	cod	sprat	herring
Adult growth	statistical	x	x	x
Integrated stock recruitment	statistical	x	x	x
fecundity	statistical	x	x	x
Egg hatch success	statistical	x	x	x
Pelagic stage survival	Individual-based modelling	x	x	x

