SUPPLEMENTARY MATERIAL TABLE S1

MODEL EVALUATION MATRICES, TABLE S1

This Model Performance and Characteristics Matrix followed by a Model Summary (Abstract) is used in the international survey on existing models taking into account previous reviews of bio-economic fisheries models Worldwide including North American, Australian, and European reviews. First, the generic model evaluation matrix is given together with explanatory notes for the rows in this model performance and characteristics matrix. After this, the individual model matrices are presented.

Model Performance and Characteristics Matrix template used for collecting information on individual model approaches

Case Study / Model	
Authors / Contact Persons*	
Aim: Management addressed, management objectives	
Aim: Corresponding advice needed/ addressed	
Institutional Set-up: (Bodies involved, needed partners);	
Type of Model (ecol, econ, soc., long-term, short-term)	
Model Dimensions and Model Structure	
Usefulness of the Model (Pro, Cons, Problems)	
Focus and Trade offs	
Data needed	
Data available Used in case study/model	
Status for application / implementation	
Model Platform and Programming Language (free, commercial)	
Model output (format)	

1.1 The Model Evaluation Matrices summarizes most importantly the below information which gives explanatory text to the rows in the survey table on the models with respect to the collective experience with and collective consensus on the models which has mainly been given by the model developers

1) *Management questions addressed and/or relevant management questions the model can address*: Aim and management objectives addressed such as biological or socio-economic objectives? Recipients: intended / realized in management? Type of regulatory framework? Harvest rules addressed, e.g. can the model address impact of technical measures?;

2) *Corresponding advice (biological and economic) the model provides*: What type of advice such as biological/economic/social advice (according to objectives, reference points, etc.)? Which indicators are produced for advice (see also usefulness of the model below)? Time frame on short (1 year) to medium term (2-3 years) current advice and/or medium (2-3) to long term (>3) strategic advice? Whether and how the model has been used in advice, i.e. has it been used in relation to advice and management? Type of results coming from the use and implementation of the model (see also usefulness and implementation of the model below)? Other models use of output from the model? Intended / realized recipients?

3) *Institutional set-up and platforms for the model*: This is split up in relation to management and advice and scientific purposes, but also in relation to who is involved and necessary to involve in developing, informing and implementing the model (see also needed partners below). In both cases it shall indicate where and in which context the model was developed and/or used and/or where supposed to be used (should be used), i.e. split into intended / realized. Also, information on whether model output has been validated or not is given here.

4) *Needed partners*: Involved partners and/or needed partners for partly developing, informing, using, and implementing the model? This involves contributions and information from stakeholders (e.g. industry, management, advice, science), needed partners, platforms, capacity building, etc. Also it includes information on whether the model has been well scientifically documented or not?

5) *Type of model*: Ecological (biological), Economic, Bio-Economic, Socio-Economic, i.e. type and characteristics with respect to which modules the model contains such as biological, economic, fleet, management, implementation, etc.? What is the orientation of the model with respect to management regimes (types) it can address, e.g. both input and output controls or can it only handle one orientation? Also, to address this, it is informed what level and complexity of the systems the models address and was intended to address (complex or simple type model), time range in form of short to me-

dium term advice/management or/and medium-long term strategic advice/management with respect to type of model? Which level or part of the system does the model address (ecosystem/multi-species/single stock, economic system, sociological system)? What spatial and temporal resolution does the model operate on? Are there behavioral models included such as RUM (Random Utility Models) to model human behavior in the model, i.e. is behavior explicit (behavior as high uncertainty factor)? What type of model with respect to e.g. analytical tool/observation model, simulation model (scenario simulation), deterministic or stochastic model, iteration (MCMC) model, or other? Is the model capable of performing a projection or static scenarios? Can the model consider uncertainty (and in given case on which parameters)? Can sensitivity tests be performed with the model (and in given case with which method and on which parameters)?

6) *Model linking, coupling and level of integration (linked to type of model)*: What level of integration of biology, economy, and sociology is there in the model and what are the links between the components, e.g. how are the economic and biological components linked to provide management advice? Coupling of biological-economic-social operating models: dynamic / static / equilibrium e.g. static representation of the economy? Is there dynamic full feed-back and integration between modules, i.e. is it fully integrated and highly detailed or is it a less integrated, simple or static model? Micro-scale or macro-scale feed-back? Feed-back according to strategic or tactic

goals of the model? Uncertainty in feed-back models in relation to medium term or long term projections?

7) *Model dimensions and model structure*: Model dimensions and scales (spatial explicit with flexible spatial dis-aggregation and/or area specific and/or regional and/or global? Seasonal explicit with months or seasons or only yearly based? Single stock and/or multi-species and/or ecosystem? Age and/or length and/or species structured? Fishery system with specific fisheries or broader to all fisheries? Only catch sector economics or broader socio-economics or marine cross sector economics? National or regional? Does the model cover the level of detail needed to capture realism sufficient for management – for example can the model provide Total Allowable Effort (TAE) and investigate how that TAE can be optimized by altering closure regimes and calculating changes in fleet efficiency to achieve the TAE)? Main components of the model, e.g. separate components for the biological and economic procedures?

8) *Data required*: Model input, data need, parameters, and functions (with respect to data need what resources and information is required such as high or low quantity of data need? Including specification of model variables and parameters – both endogenous and exogenous? Requirement of data from special databases and/or sampling systems e.g. logbooks, e-logbooks, sales slips, effort databases, VMS data, broader socio-economic databases, etc.? Available data (data collection frameworks)? Any estimations necessary or data processing

needed before the model can be applied? Handling data rich or data limited systems; with respect to values such as market values or broader non-market values what does the model use: consumer utility functions, price elasticity, non-market values for certain species groups, shadow values with the protection of species, can the model follow a value chain and how far, etc.?

9) *Usefulness of the model*: In which context is it useful and where are detected problems (pro, cons, limitations, problems) - this is mainly in respect of use and implementation but naturally also addresses the development of the models? Qualitative or quantitative indicator based output? Usefulness of the model output indicators and model performance criteria (and robustness and risk assessment)? Is parameter estimation stochastic or deterministic? Simulation (what if) or optimization of objective function (what´s best) or both?

10) *Focus and trade-offs (linked to usefulness above)*: What is (and can be) addressed in the models and case studies (main aim of the model and main questions to be answered and main scientific/advisory/management scenarios/options/problems to be addressed)? How is the model used (generic or case specific; strategic or tactical; short to medium term or long term)? Is the model balanced according to trade-offs between using fully integrated and highly detailed dynamic models or less integrated, simpler or static models?

11) *Status for the development, application, implementation and use of the model in case studies*: Progress of linking biological and economic operating models or parts in the models? Model use in advice and/or management as well as decisions hereunder – and how or why not? What makes the model informative and useful to policy makers and stakeholders (user-friendliness, flexibility, complexity)? What improves or impedes the model acceptance and how can we best communicate the model and its results? The challenges and processes involved in the model implementation? Important to obtain information from the model developers on this as well as on the progress and problems in this, and why it is so? Is the model well documented scientifically? Is the model only developed and used for scientific purposes?

12) *Dissemination of the model*: References for scientific literature and technical and advisory reports - including a reference list for each model? Model user guides? Model web sites?

For each of the above bullets the answers could be given according to a scaling of the degree / level (of the models), i.e. low, medium, high.

As such each bullet (row or column) could be used as an axis in a multi-dimensional diagram showing the coverage of all the models according to this scaling.

1.2 Individual Model Evaluation Matrices included in the survey

Crab Ocean Acidification Model (CRAB ACID)

Case Study / Model	Crab Ocean Acidification Model (CRAB ACID)
Authors / Contact Persons*	Andre Punt, aepunt@u.washington.edu
Aim: Management addressed, management objectives	Selection of target fishing mortality rates to achieve Maximum Economic Yield and Maximum Sustainable Yield
Aim: Corresponding advice needed/ addressed	Indicators produced: MSY, MSY, F_{MSY}, F_{MEY}, $F_{35\%}$ as a function of time.
Institutional Set-up: (Bodies involved, needed partners);	NOAA: (a) Provision of experimental data on the impact of ocean acidification on survival rates of larvae and benthic animals and on hatching rates; (b) provision of data for assess stock status; (c) provision of data on costs and prices UW: Development of models for pre-recruit crab and adult crab
Type of Model (ecol, econ, soc., long-term, short-term)	Three models: (a) pre-recruit dynamics; (b) post-recruit dynamics; (c) a model that computes economic outputs. Uncertainty is quantified through bootstrapping.
Model Dimensions and Model Structure	Male only; length-structured
Usefulness of the Model (Pro, Cons, Problems)	The model is fundamentally strategic
Focus and Trade offs	N/A
Data needed	Relationships between survival and ocean acidification; stock assessment outputs.
Data available Used in case study/model	As Above
Status for application / implementation	Not used for management at this point in time.
Model Platform and Programming Language (free, commercial)	R and FORTRAN
Model output (format)	Text file output

Crab ABC (Allowable Biological Catch) Model (CRAB ABC)

Case Study / Model	Crab Allowable Biological Catch (ABC) Model (CRAB ABC)
Authors / Contact Persons*	Andre Punt, aepunt@u.washington.edu
Aim: Management addressed, management objectives	The US MSA requires that "overfishing" be avoided. This is achieved by implementing a buffer between the overfishing level (the catch corresponding to MSY) and the Acceptable Biological Catch / Total Allowable Catch. The aim of the model was to identify trade-offs between the probability of overfishing and the impacts of revenues from the fishery.
Aim: Corresponding advice needed/ addressed	Biological Indicators: (a) trends in Mature Male Biomass and fishing mortality; (b) trends in revenue. Indicators are provided by year
Institutional Set-up: (Bodies involved, needed partners);	(a) NOAA / ADFG provide the data used for stock assessment purposes; (b) NOAA provides the data on revenue; (c) review is undertaken by the Crab Plan Team of the North Pacific Fishery Management Council (NPFMC); (d) the decision on buffer levels was taken by the NPFMC.
Type of Model (ecol, econ, soc., long-term, short-term)	The model is the combination of a standard sex- and length-structured population dynamics model, combined with a Management Strategy Evaluation module that quantifies assessment and management uncertainty, combined with a model of fishing revenues
Model Dimensions and Model Structure	Applied by stock; the population dynamics model is sex-, length-, and maturity state-structured. There are separate modules for the biological and economic components. Each stock falls into a different "tier" depending on the quality of the assessment
Usefulness of the Model (Pro, Cons, Problems)	The biological models are used for the provision of management advice. The entire bio-economic model formed the basis for a decision by NPFMC for a buffer for crab stocks.
Focus and Trade offs	The aim of the model was to identify trade-offs between the probability of overfishing and the impacts on revenues from the fishery (see Fig. 8 of the published paper for an example)
Data needed	Prices, survey indices, catches by fleet, length composition data form fisheries and surveys
Data available Used in case study/model	See above
Status for application / implementation	Completed. The decision on a Buffer was made
Model Platform and Programming Language (free, commercial)	R, ADMB, FORTRAN
Model output (format)	Text files

174 Multispecies Stock Production Model (MSPM)

Case Study / Model	Multispecies Stock-Production Model (MSPM)
Authors / Contact Persons*	Jan Horbowy (horbowy@mir.gdynia.pl)
Aim: Management addressed, management objectives	Biological assessment of stock status and advice on catch quotas, taking into account predator-prey interactions. The model may be used to estimate historical biomass of fish stocks interacting through predator-prey relations and to predict the biomasses and catches under range of options of fishing mortality. Harvest control rules may be included. Technical interactions are not addressed.
Aim: Corresponding advice needed/ addressed	Biological advice, including options for defined biological reference points, e.g. MSY and PA reference points. Short-, medium-, and long-term advice is possible.
Institutional Setup: (Bodies involved, needed partners);	National Marine Fisheries Research Institute, Gdynia, Poland Published in peer-reviewed journals. Applied and described within FP7 project BECAUSE.
Type of Model (ecol, econ, soc., long-term, short-term)	Biological, multispecies (predator-prey interactions), statistical model. Prediction part may include stochasticity and be run on short-, medium-, and long-term.
Model Dimensions and Model Structure	Multi-species: interacting stocks, which may be separated into young and adult fish components. It is possible to include seasons.
Usefulness of the Model (Pro, Cons, Problems)	Model is useful if age determination is problematic or not available. The model is relatively simple, so many simulations may be performed in a short time. It is possible to use the model in some situations when individual growth rate shows trends or dependencies. So far the model was applied only in the Baltic with three interacting stocks: cod, herring, and sprat. The application of the model to more stocks has not been tested, although it should be possible.
Focus and Trade offs	The model provides estimates of predation mortality of prey stocks (including cannibalism) and biomass consumed by predator. Estimates of stock biomass and fishing mortality are also provided.
Data needed	Landings, fishing effort or survey indices of stocks biomass, recruitment indices or recruitment sub-models, food composition (stomach contents) of predator, growth parameters, residual natural mortality
Data available Used in case study/model	For Baltic stocks above data are available from DCF data and ICES data base
Status for application / implementation	So far the model has been used for scientific purposes. There was not need to apply it for management in the Baltic as age structured models are in use.
Model Platform and Programming Language (free, commercial)	Model has been developed in Excel, including Excel macros to provide bootstrap estimates of parameters variance and to run retrospective analyses.
Model output (format)	Excel tables and graphs

Stochastic Age-Structure Optimization Model (STOCH HCR)

Case Study / Model	Stochastic Age-Structure Optimization Model (STOCH HCR) = Northern and Southern Hake Age-Structure Optimization Model (N/S HAKE ASM); Northern and Southern Stock of Hake in Western Waters.
Authors / Contact Persons*	*Jose Maria Da-Rocha (jmrocha@uvigo.es); *Santiago Cerviño (santiago.cervino@vi.ieo.es); *Maria Jose Gutierrez (mariajose.gutierrez@ehu.eus); Javier Garcia-Cutrin (fjgarcia@uvigo.es); Ernesto Jardim ernesto.jardim@jrc.ec.europa.eu; Rosa Mato-Amboage (rma523@york.ac.uk); Jaume Sempere (jsempe@colmex.mx) and Luis Taboada-Antelo (ltaboada@iim.csic.es)
Aim: Management addressed, management objectives	Assess the biomass status with respect to sustainability, provide target values (Reference Points), to ensure the fishery is managed under the objective of maximum economic yield, and to provide the optimal fleet costs structure given (individual transferable) quotas and technical regulations.
Aim: Corresponding advice needed/ addressed	Four Tools to provide: Long Term Socio-economic advice: Assess the impact of introducing ITQ's (or changes in technical measures) on Wealth and Revenue Lorenz Curves and compute their corresponding Gini coefficients. Medium Term Bio-economic advice: Generate effort levels required to achieve Target Reference Point (single/multispecies MEY's) or evaluate Recovery Plans. Short Term Biomass status advice: Design HCR to achieve risk targets when managers regard their models as approximations (HCR in MSE Framework). Generate SSB values, probability of SSB being above a certain reference point, etc. Very Short Biomass status advice: Assess the New Generation of Management Plans where fishing mortality rates can float within certain margins of fluctuations around a fixed central rate in line with the MSY principle.
Institutional Set-up: (Bodies involved, needed partners);	Used by STECF for evaluating the northern hake management plan in 2008, the Sothern Hake recovery plan in 2010-2011 and SWW & NWW Multiannual Management plan in 2015. Model integrated within several EU projects (FP7 MYFISH and MINOUW).
Type of Model (ecol, econ, soc., long-term, short-term)	Long Term Socio-economic advice: General Equilibrium with Stochastic Dynamic Optimization generate (endogenous) fleet size distribution Medium Term Bio-economic advice: Age-Structured Dynamic Optimization to design optimal paths towards MEY's. Short Term Biomass status advice: (Robust) Linear Quadratic Gaussian Age-Structured models to design optimal paths around Biomass Targets. Quarterly Biomass status advice: VAR Model to forecast (Endogenous) Fishing Mortalities Fluctuations using the observed fleet behavior.
Model Dimensions and Model Structure	It was implemented for Northern and Southern Hake fisheries (with four fleet segments and four target species.
Usefulness of the Model (Pro, Cons,	Pros: The four tools were designed using analytical (close form) solutions. Therefore the model can be implemented in any multi-

Problems)	fleets, multi-species, multi-stocks and multi-seasons case study. Cons: A problem in the use of analytical solutions is that the model must be solved by users (there is no friendly interface that can capture data from external sources and generate results).
Focus and Trade offs	The model does not include for the moment the fish size dimension. Therefore its focus is technical interactions rather than species interactions. Species interactions are introduced as vector (stochastic) auto-regressive processes (VAR's).
Data needed	The model uses standard age structure population dynamics data (single stock assessment and advice) and standard economics (Gini Coefficients, DCF data).
Data available Used in case study/model	Age structure population dynamics from ICES WG, Catch/effort data from a daily sales survey.
Status for application / implementation	The model is being continuously developed to address further issues.
Model Platform and Programming Language (free, commercial)	Windows and Mac. Model written in MATLAB. However, analytical solutions allow to implement the model in any programming code (Excel, R, Matlab, Gauss)
Model output (format)	Flat text files.

ITQ_Wealth Model (ITQ WEALTH)

Case Study / Model	ITQ Wealth Model (ITQ WEALTH): Wealth Distribution in Markets with Output Permits: Do Permanent Transfers Increase Inequality? An Example from the US Northeast (groundfish) Fishery.
Authors / Contact Persons*	José María Da-Rocha jmrocha@uvigo.es Rosa Mato-Amboage rosa.mato@uab.cat
Aim: Management addressed, management objectives	- We are interested in evaluating whether the permanent transfer of quotas increases wealth inequality. -We build a dynamic general equilibrium model of firm dynamics in a natural resource industry that is managed with output permits. -To study the distributional impact of imposing restrictions on permanent transfers we compare the (endogenous) firm productivity distribution of an industry with permanent individual transferable quotas to the one with non-permanent transferable quotas.
Aim: Corresponding advice needed/ addressed	-We find that allowing permanent transfers will affect revenues and wealth inequality in a different way. Revenues inequality is related with the productivity distribution of incumbent firms. When permanent transfers are allowed the less productive firms can choose to sell and leave. This option, increases productivity concentration and raises revenues inequality. However, if investment in productivity is an endogenous decision, there exists a second effect in the opposite direction. When permanent transfers are allowed firm incentives to invest in productivity are lower. As a result, if the cost volatility is high, i.e. if idiosyncratic shocks are important, permanent trade does not necessarily increase revenue inequality. -However, the effect of permanent transfers on wealth inequality is related to the wealth distribution of all firms. Permanent transfers always increase the wealth of the less productive firms, those who sell their quota. Therefore, given that all the firms which exit sell

	their quota at the same price, independently of their productivity, permanent transfers can generate a more egalitarian wealth distribution, even when revenues distribution of incumbent firms become more unequal.
Institutional Set-up: (Bodies involved, needed partners);	Needed partners: project managers, to obtain economic data before and after the introduction of ITQs.
Type of Model (ecol, econ, soc., long-term, short-term)	Economic. We build a Stochastic General Equilibrium Model of firm dynamics.
Model Dimensions and Model Structure	The economic environment is as follows: -There are two agents (incumbent and entering firms) -Four markets (final goods, labor, an output permit lease market, and a permanent output permit market) -Two market configurations: permanent (and not permanent) transfers of quotas The decision making: -Incumbent firms – Decide whether or not to exit the industry – Those who stay, demand labor and produce goods using output permits -Entrant firms – Entrants to the industry must purchase the permit to operate – Entry will occur if expected profits are positive
Usefulness of the Model (Pro, Cons, Problems)	-Pros: Allows us to account for the changes in the cost distribution and value functions, which not only take into account the active vessels, but the value obtained by all agents in the model. - Cons: Simplify ownership structure of quotas and how they are initially allocated.
Focus and Trade offs	Firm dynamics stationary cost distributions and value functions
Data needed	Economic data on inequality, profits, costs, prices, and quotas before and after the introduction of ITQs
Data available Used in case study/model	We look at the 2010 Final Performance Report on the US Northeast Multispecies Fishery. Some of the data used for calibration: -Improvement in economic performance (gross nominal revenue per unit effort and vessel owners' share of nominal net revenue per day) -Decrease in active vessels and the effort became more concentrated (there were 17% fewer active vessels in 2010 than in 2007 48% fewer trips) -Increase in concentration of gross nominal revenues among top earning vessels (about 68% of gross nominal revenues from groundfish sales during 2007-2009 resulted from landings by 20% of active vessels. In 2010, 20% of vessels accounted for about 80% of the gross nominal revenues from sales)
Status for application / implementation	We use the calibrating model to understand the mechanisms behind wealth generation in an industry where permanent transfers increases productivity of incumbent firms and raises revenues inequality.
Model Platform and Programming Language (free, commercial)	Matlab (commercial)

Model output (format)	We obtained an analytic solution for the vessels stationary distribution in a continuous-time stochastic dynamic general equilibrium setup. We calibrated the model to evaluate the impact of ITQs on revenue inequality and wealth inequality.

Economic Interpretation of ICES Advisory Committee (ACOM) for fisheries management (EIAA).

Case Study / Model	Economic Interpretation of ACOM Advice (EIAA).
Authors / Contact Persons*	Hans Frost hf@ifro.ku.dk; Ayoe Hoff ay@ifro.ku.dk; Jesper L. Andersen jla@ifro.ku.dk; Thomas Thøgersen thta@aqua.dtu.dk; IFRO. JRC and DG MARE also possible.
Aim: Management addressed, management objectives	To carry out an economic interpretation of the ACFM advice submitted to the STECF about annual TACs.
Aim: Corresponding advice needed/ addressed	Advice needed from ICES (ACFM) about stock assessment.
Institutional Setup: (Bodies involved, needed partners);	All EU member States, JRC and STECF.
Type of Model (ecol, econ, soc., long-term, short-term)	Deterministic economic model used for projections with spawning stock biomass and TAC/landings as exogenous input variables.
Model Dimensions and Model Structure	1) Country 2) fleet segments 3) stocks (management area), and 4) year.
Usefulness of the Model (Pro, Cons, Problems)	The model is designed to work with EU data collected by STECF (JRC) in order to supplement biological advice about TACs. In particular short run projections. Long term projection possible.
Focus and Trade offs	Focus is on economic short term projections on fleet segment level of advice about fish stocks. Number of vessels is constant. Among spin offs are long term projections, economic consequences of variable number of vessels, optimization of effort, sensitivity analyses.
Data needed	DCF
Data available Used in case study/model	Used by JRC, STECF, DG MARE and others for economic assessment of annual TACs.
Status for application / implementation	Used for economic interpretations of annual TAC/quota advice within the EU.
Model Platform and Programming Language (free, commercial)	Excel.
Model output (format)	1) Gross revenue; 2) Crew remuneration; 3) Gross cash flow; 4) Net profit. The general output is supplemented by output on the same level of indicators as included in the DCF.

Bio-Economic Model of European Fleets (BEMEF).

Case Study / Model	Bio-Economic Model of European Fleets (BEMEF, extended EIAA)
Authors / Contact Persons*	Griffin Carpenter griffin.carpenter@neweconomics.org; Aniol Esteban aniol.esteban@neweconomics.org
Aim: Management addressed, management objectives	To model the potential economic benefits of a long-term MSY state, issues in quota allocation, and the economic implications of annual TAC advice.
Aim: Corresponding advice needed/ addressed	Tactical economic advice.
Institutional Set-up: (Bodies involved, needed partners);	The JRC and ICES are involved for data provision.
Type of Model (ecol, econ, soc., long-term, short-term)	Multi-period deterministic static equilibrium economic model.
Model Dimensions and Model Structure	Country, fleet segments, stocks, year.
Usefulness of the Model (Pro, Cons, Problems)	The model is designed to work around data reporting from the DCF and ICES for easy annual updates. There is a user-friendly Excel structure and a simplified online tool for quick analysis. Both versions have a wide breath with around 200 EU fleets covered. The model is unique in trying to provide an adjustable long-term projection and also in attempting to address quota allocation scenarios. The model is comparably weaker on ecosystem interactions and more complex aspects of behavioural change. As changes to TAC is a major dynamic and limiting variable the model does not cover non-TAC (Mediterranean) fleets. Currently the model provides insight on static periods but does not model the potential transition periods between the periods.
Focus and Trade offs	The model is focused on the macro picture of EU fleets. There is a trade-off between breadth and depth with a large number of fleets covered but little multi-species and multi-fleet impacts that characterise a particular area.
Data needed	The main data sources are the DCF for economic data at the fleet level and ICES stock assessments. Any recent data on fish prices, fuel prices and vessel numbers can be used, as well as results from studies on fish price flexibility and fish schooling parameters. Data on landings by port by fleet type can be used to extend the results to communities and secondary industries.
Data available Used in case study/model	Used by NEF for a 2015 report *Managing EU Fisheries in the Public Interest* and by the JRC for the *2015 Annual Economic Report of EU Fishing Fleet*.
Status for application / implementation	Model is available for download and use. Currently undergoing update for the 2016 AER (2014 data) and some changes highlighted in the "Work in progress" documentation.
Model Platform and Programming Language (free, commercial)	Full model is developed and available for download in Excel with a simplified version online at www.fisheriesmodel.org
Model output (format)	Eight explicit outputs per fleet: landings, gross earnings, value added, net profit, fishing jobs, wages, carbon, processing jobs. More outputs (costs) available on other tabs.

Ecological Modelling of Multiannual Quota (MAQ)

Case Study / Model	**Ecological Modelling of Multiannual Quota (MAQ) in Dutch plaice fishery**
Authors / Contact Persons*	Diana van Dijk (diana_van_dijk@yahoo.com); René Haijema (rene.haijema@wur.nl); Eligius Hendrix (eligius.hendrix@wur.nl); Rolf Groeneveld (rolf.groeneveld@wur.nl)
Aim: Management addressed, management objectives	The model is developed to analyze the economic impact of implementing multiannual quota
Aim: Corresponding advice needed/ addressed	Setting quota for more than one year
Institutional Setup: (Bodies involved, needed partners);	Developed at Wageningen University. Data from official publications LEI and IMARES.
Type of Model (ecol, econ, soc., long-term, short-term)	Bi-level bioeconomic stochastic dynamic programming model solved with value function iteration.
Model Dimensions and Model Structure	Two actors (government and fishers); one fleet; one fish stock; one capital stock. Stock variables discretized to 23 equidistant levels. A third stock variable, quota, is discretized to 28 equidistant levels.
Usefulness of the Model (Pro, Cons, Problems)	Pro: Optimization of Harvest Control Rules given assumed fishers' investment decisions Con: single fish stock (case study, Dutch demersal fishery, is mixed); government assumed to anticipate fisher behaviour but not vice versa
Focus and Trade offs	Trade-off between economic efficiency and quota stability
Data needed	Costs and prices of fish, fuel, and fishing capital; r and K of Gordon-Schaefer growth function; σ of multiplicative distortion term in growth function
Data available Used in case study/model	Costs and prices of fish, fuel, and fishing capital: LEI data; r and K of Gordon-Schaefer growth function: ICES and IMARES; σ of multiplicative distortion term in growth function: ICES data
Status for application / implementation	Application to North Sea plaice is published in a peer-reviewed journal
Model Platform and Programming Language (free, commercial)	Matlab (commercial)
Model output (format)	

Ecological Modelling of Multiannual Quota with Adjustment Restriction (MAQ-ADJ)

Case Study / Model	**Ecological Modelling of Multiannual Quota with Adjustment Restrictions (ADJ-MAQ) in Dutch plaice fishery**
Authors / Contact Persons*	Diana van Dijk (diana_van_dijk@yahoo.com); René Haijema (rene.haijema@wur.nl); Eligius Hendrix (eligius.hendrix@wur.nl); Rolf Groeneveld (rolf.groeneveld@wur.nl)
Aim: Management addressed, management objectives	The model is developed to analyze the economic impact of restrictions on quota adjustments, i.e. the restriction that quota are to change no more than 15% each year.
Aim: Corresponding advice needed/ addressed	Restrictions on TAC adjustments
Institutional Setup: (Bodies involved, needed partners);	Developed at Wageningen University. Data from official publications LEI and IMARES.
Type of Model (ecol, econ, soc., long-term, short-term)	Bi-level bioeconomic stochastic dynamic programming model solved with value function iteration.
Model Dimensions and Model Structure	Two actors (government and fishers); one fleet; one fish stock; one capital stock. Stock variables discretized to 23 equidistant levels. A third stock variable, quota, is discretized to 28 equidistant levels.
Usefulness of the Model (Pro, Cons, Problems)	Pro: Optimization of Harvest Control Rules given restrictions on adjustment and assumption on fishers' investment decisions Con: single fish stock (case study, Dutch demersal fishery, is mixed); government assumed to anticipate fisher behaviour but not vice versa
Focus and Trade offs	Trade-off between economic efficiency and surplus fishing capacity
Data needed	Costs and prices of fish, fuel, and fishing capital; r and K of Gordon-Schaefer growth function; σ of multiplicative distortion term in growth function
Data available Used in case study/model	Costs and prices of fish, fuel, and fishing capital: LEI data; r and K of Gordon-Schaefer growth function: ICES and IMARES; σ of multiplicative distortion term in growth function: ICES data
Status for application / implementation	Application to North Sea plaice is under revision with a peer-reviewed journal
Model Platform and Programming Language (free, commercial)	Matlab (commercial)
Model output (format)	

DISPLACE Individual Vessel Based multi-fleet and multi-stock Bio-Economic Model (DISPLACE)

Case Study / Model	DISPLACE, a dynamic, individual based model for spatial planning and fishing effort displacement
Authors / Contact Persons*	François Bastardie, fba@aqua.dtu.dk , J. Rasmus Nielsen, rn@aqua.dtu.dk , DTU-Aqua; www.displace-project.org
Aim: Management addressed, management objectives	Evaluation of short- and medium term fleet and vessel-based management on effort allocation, cost- and energy efficiency according to management plans; Biological objectives addressed; Maritime spatial planning and bio economic consequences of fishing effort displacement can be addressed when established;
Aim: Corresponding advice needed/ addressed	Short and medium term, LTMP, multi-fleet and multi-stock based advice on efficient effort allocation: Partial fishing mortalities by fishery/métier/vessel given efficiency in effort allocation; Advice aimed towards ICES and EU STECF and National Administrations; Model scientific published and used in scientific research projects but not applied, implemented and used in actual advice yet;
Institutional Set-up: (Bodies involved, needed partners);	Development, establishment and publication of the model (scientific documentation): university and fisheries research institutes (DTU Aqua and research partners); Model published in scientific journals; Intended implementation into advice: ICES and EU STECF and National administrations;
Type of Model (ecol, econ, soc., long-term, short-term)	Spatial and individual vessel based bio-economic simulation framework which combines a spatial fishing behavior model at high resolution and spatial population models; Short term to medium term scenario evaluation of multi-stock and multi-fisheries ecological-economic systems; Need detailed information on spatio-temporal disaggregation of the fishing activities, the resources and possibly the various utilizations of the sea.
Model Dimensions and Model Structure	Operating with individual vessels belonging to fleets and fisheries (e.g. EU DCF metiers). Biological OM on species and stock level covering several stocks (in e.g. mixed fisheries) with high resolution spatio-temporal abundance and resource availability information from research surveys. Length and age based model.
Usefulness of the Model (Pro, Cons, Problems)	Cons: Complex model that needs very detailed data; Need some computational power and programming skills to be operated; Difficulties in accessibility of data, high complexity and uncertainty in the parameterization e.g. data and processes with various time and spatial scales. Pros: Bi-directional model i.e. account for fish and fishermen reactions in the assessment of management actions; Highly spatially resolved; Make use of the newly available information such as VMS data; Parameterization facilitated by a set of routines written in the R language.
Focus and Trade offs	IA and possibly MSE of MPs with respect to effort allocation, energy use and cost-efficiency in the catching sector; Account for biological and economic incentives/logics in fisheries behavior via decision choice modeling; Computation of a variety of economic indicators of interest for fisheries sustainability, particularly regarding fuel consumption; Legitimate approach in the current regulation context that promotes

	the development of marine protected areas and individual quotas.
Data needed	• High resolution catch (weight and value) and effort from trip based log-book information and Satellite VMS -information (i.e. logbook coupled to VMS data). • High resolution resource availability data from e.g. disaggregated research survey or combined fishery information on disaggregated resource availability (at least on ICES Square). • Stock assessment and fishbase data. • STECF landings data per ICES square. • Various maritime spatial uses.
Data available Used in case study/model	The model has been used so far to evaluate the efficiency of effort allocation scenarios on the whole Danish fisheries based on log-books, VMS, EU DCF, and STECF data coupled to the dynamic of a range of North Sea and Baltic Sea commercially important species.
Status for application / implementation	Model developed and tested; Model published in international peer reviewed scientific journals; Model not implemented in advice;
Model Platform and Programming Language (free, commercial)	Core model written in C++; Parameterization (incl. coupling of log-books and sales slips to VMS data) and model output analyses written in the R freeware.
Model output (format)	Partial fishing mortality by stock, effort, value of catch and profit by vessel and trip (which can be summed up to e.g. metier and quarter/year). Furthermore, energy use and energy efficiency measures (e.g. value or amount of catch per unit of energy (fuel). Usual stock indicators (R, F, SSB).

ISIS-Fish Bay of Biscay demersal fishery (ISIS FISH)

Case Study / Model	ISIS-Fish Demersal fishery in the Bay of Biscay
Authors / Contact Persons*	Stéphanie Mahévas* & Michel Bertignac; Stephanie.Mahevas@ifremer.fr; michel.bertignac@ifremer.fr
Aim: Management addressed, management objectives	Hake restoration plan Multiple species management plan (in discussion) : Bmsy and Fmsy for Hake, Sole and Nephrops Spatial management measures, technical management measures can be addressed by the model
Aim: Corresponding advice needed/ addressed	quantitative comparisons of consequences of various management measures (more specifically MPA and selectivity measures) for model Hake, Sole and Nephrops using model outputs (see below) and reference points (Bmsy and Fmsy) the model has not yet been used in advice. We project to couple the model with SS3 for Hake in order to perform MSE.
Institutional Setup: (Bodies involved, needed partners);	Ifremer(Nantes, Brest), some implication of economists within Benthis project Interactions with stakeholders within RAC and a regional project (Coselmar)
Type of Model (ecol, econ, soc., long-term, short-term)	bio-economic spatially explicit model • length-structure population dynamics for Hake and Nephrops • Sole population dynamics should be included • fishing exploitation (métier, RUM for fishermen behavior in reaction to past and management restrictions) the model is deterministic but we used statistical framework mainly based on sensitivity analysis to simulate various scenarios for uncertain process (like recruitment for instance) and to provide range of variation of outputs a specific module of the tool is dedicated to global sensitivity analysis (Morris, LHS, etc.. methods can be easily performed) and uncertainty analysis 10-years simulation
Model Dimensions and Model Structure	2 species (3 in 2014), French fleets, Spanish fleets spatial resolution : ICES rectangle temporal resolution : month Area : 8a and 8b (Bay of Biscay)
Usefulness of the Model (Pro, Cons, Problems)	usefulness : • reproducing spatial interactions between marine populations and fishing activities (technical interactions, bycatch, discards,...) • standardizing fishing effort (through technical characteristics, fishing behavior, ...) • anticipating fisheries dynamics and status when changing management; • better understanding of the fisheries; • uncertainty analysis to assess the robustness of the measure to reach management objectives • difficulties to estimate accessibility
Focus and Trade offs	focus on hake and nephrops
Data needed	Fish biology and life traits, state of the studied stocks, fish and fish-

	ing areas, fishing activity, management options. All these parameters are estimated outside the model using logbooks, VMS, scientific survey, ICES evaluations.
Data available Used in case study/model	except for accessibility and some economic parameters (cost at métier scale), data needed are available
Status for application / implementation	calibration in progress, should be operational in June 2014
Model Platform and Programming Language (free, commercial)	ISIS-Fish (free) in Java http://www.isis-fish.org/en/index.html
Model output (format)	Biomass per length group, per rectangle, per month Catch per metier, per fleet, per rectangle, per month Discards per metier, per fleet, per rectangle, per month F per metier, per fleet, per rectangle, per month Total F Revenues per metier, per fleet, per month or per year (net or gross) Various indicators derived from above variables (csv files)

ISIS-Fish Bay of Biscay pelagic fishery (ISIS FISH)

Case Study / Model	ISIS-Fish Pelagic fishery in the Bay of Biscay
Authors / Contact Persons*	Sigrid Lehuta*, Youen Vermard, Stéphanie Mahévas & Pierre Petitgas
Aim: Management addressed, management objectives	Anchovy management plan and spatial and seasonal closures Multiple species trade off: fishery targeting Anchovy, sardine, seabass and tuna sequentially.
Aim: Corresponding advice needed/ addressed	quantitative comparisons of the consequences of various management measures (more specifically MPA and harvest control rules) for anchovy
Institutional Setup: (Bodies involved, needed partners);	Ifremer (Nantes), implication of biological oceanographers on larval dispersion and economists, particularly regarding fuel costs. Interactions with stakeholders within a regional project (PPDR)
Type of Model (biol, econ, soc., long-term, short-term)	Bio-economic multi-fleet, multi-species spatialised model. Spatially interacting fish and fishing dynamics. • Matrix model for anchovy (stage-structured) • Surplus production models for seabass, sardine and tuna • Random utility model to predict effort distribution on métiers in reaction to management Focus on short- to medium-term forecasts (10 years).
Model Dimensions and Model Structure	4 species, 5 populations 4 French fleets (pelagic trawlers and purse seiners), 1 Spanish fleet (purse seiners) spatial resolution : ½ ICES rectangle (0.5° x 0.5°) temporal resolution : month Area : 8a, b and c (Bay of Biscay)
Usefulness of the	usefulness :

Model (Pro, Cons, Problems)	• anticipating fisheries dynamics and status when changing management; • better understanding of the fisheries; • uncertainty analysis to assess the robustness of the measure to reach management objectives Difficult to predict Anchovy recruitment and spatial distribution.
Focus and Trade offs	Focus was made on Anchovy biology and spatial dynamics in relation with the evaluation of spatial closures. Time series of spatialised larvae survival obtained from a bio-physical model of larval drift, growth and survival were used to force the model and improve the description of recruitment variability. Low level of details on the other populations (no spatialisation, surplus production models). Emphasis was also put on the choice of métier (target species and area of practice) in reaction to the regulatory, ecological and economic context, through the first integration of random utility models in the simulator.
Data needed	Fish biology and life traits, state of the studied stocks, fish and fishing areas, fishing activity, management options
Data available Used in case study/model	Logbooks, VMS, scientific survey, ICES assessment reports, outputs of bio-physical model. Except for accessibility and some economic parameters (cost at métier scale), data needed are available.
Status for application / implementation	The model was used to evaluate recovery plans for anchovy as well as to identify robust indicators of management impact. Results were disseminated within the scientific community only so far. Intention is to propose the model for use in RACs and STECF.
Model Platform and Programming Language (free, commercial)	ISIS-Fish (free) in Java http://www.isis-fish.org/en/index.html Database available: http://www.isis-fish.org/download.html /Pelagic fishery of the Bay of Biscay
Model output (format)	Time series of: Abundance/Biomass per age group, per area, per month Catch per species, per metier, per fleet, per area, per month Revenus per metier, per fleet, per month or per year (net or gross) Various indicators derived from above variables (csv files)

ISIS-Fish Eastern English Channel -7D (ISIS FISH)

Case Study / Model	ISIS-Fish Eastern English Channel (7D)
Authors / Contact Persons*	Sigrid Lehuta, Loïc Gasche, Stéphanie Mahévas, Paul Marchal sigrid.lehuta@ifremer.fr; Stephanie.Mahevas@ifremer.fr; Paul.Marchal@ifremer.fr
Aim: Management addressed, management objectives	- Harvest Control Rules for Sole, Plaice, data-limited species - Catch quota, multi-species evaluations, discard reductions - Simulate interactions between human activities (fishing, sediment extraction, windfarms) - Spatial management measures - Identify management scenarios providing higher robustness to uncertainties.
Aim: Correspond-	Quantitative comparison of management scenarios and evaluation

ing advice needed/ addressed	of associated robustness. Evidence multi-species, multi-activity trade-offs.
Institutional Set-up: (Bodies involved, needed partners);	IFREMER (Nantes, Boulogne-sur-Mer), institutions involved in the vectors, Socioec and DiscardLess projects. Implication of economists and stakeholders within the Socioec and DiscardLess projects.
Type of Model (biol, econ, soc., long-term, short-term)	Bio-economic multi-fleet, multi-species spatialised model. Spatially interacting fish and fishing dynamics. Matrix models for fish populations (age-structured) Predictive models of effort distribution on métiers (gravity model) for fleet dynamics Focus on short- to medium-term forecasts (10 years).
Model Dimensions and Model Structure	Eastern English Channel (ICES area 7D) Temporal resolution: month In order to rationalise complexity, 2 biological models, aiming to address different management questions, are currently in development in parallel and aim at being combined in the future: - Impact of fishing and aggregate extraction on flat fish and habitats Spatial resolution: 0.125°*0.125° cells (1/32nd of an ICES statistical rectangle) Species: Sole and Plaice (age-structured), proxies for Benthic communities dynamics - Multi-species evaluation of management measures from the new FCP Spatial resolution: 0.25° x 0.25° cells (1/8 of ICES rectangle) Species: Sole, Plaice, Cod, Whiting, Red mullet, Scallops(age-structured), Squids, Cuttlefish. Fleets: French fleets operating with bottom trawls, nets, beam trawls and dredges in the Eastern channel
Usefulness of the Model (Pro, Cons, Problems)	Usefulness: - Better understanding of spatial interactions between activities and populations - Evaluation of management measures including technical and spatial measures (Management Strategy Evaluation) - Evaluation of robustness of proposed management strategies - Outputs comparable to those of stock assessment working groups. Weaknesses: - Complexity (particularly due to spatial aspects) and associated simulation duration - Need for hypotheses on spatial distribution of fish populations
Focus and Trade offs	Focus is on spatial interactions between uses and resources: - Benthos, flat fish, fishing and aggregate extraction in the first case - Demersal fish and fishing activities in the second case Trophic relationships and other causes of mortality (other fleets) are not explicit but rather included as external mortality factors or increased area attractivity. Benthos communities are represented at highly aggregated level (biomass pool).

	Variability at individual level is not considered (neither for fish or fisherman).
Data needed	Fish biology and life traits, state of the studied stocks, fish population and fishing areas, fishing activity, management options, position and intensity of other activities occurring in the area. Assessment reports, scientific surveys, log-book data.
Data available Used in case study/model	Data needed is generally available, but not always at the scale that is needed for the model (spatial distribution of populations: known only at the time of the scientific surveys, economic data: available at annual scale). Accessibility of fish population to fishing is usually unknown and calibrated.
Status for application / implementation	- Non-spatial management measures tested on an early version of the model - Calibration, sensitivity and uncertainty analysis methods has been specifically developed to be adapted to such complex model - Currently used to assess management measures (landing obligation)
Model Platform and Programming Language (free, commercial)	ISIS-Fish (Java, free) http://www.isis-fish.org/en/index.html
Model output (format)	Time series of: Abundance/Biomass per species, per age group, per area Catch per species, per metier, per fleet, per area Discards per species, per metier, per fleet, per area F per species, per metier, per fleet, per area Revenues, per fleet, per métier Profits , per fleet, per métier (csv files)

Baltic FLR multi-stock and multi-fleet bio-economic fishery management evaluation model coupled to the SMS multi-species model (BALTIC FLR-SMS)

Case Study / Model	Baltic FLR Model – Coupled to SMS in the Baltic Sea (BALTIC FLR-SMS); Baltic FLR Model for Nephrops Fisheries in Kattegat; Fleet-based Management Strategy Evaluation for multi stocks (coupled to SMS stochastic multi-species model for the Baltic)
Authors / Contact Persons*	François Bastardie, fba@aqua.dtu.dk , J. Rasmus Nielsen, rn@aqua.dtu.dk , Morten Vinther, mv@aqua.dtu.dk , DTU-Aqua
Aim: Management addressed, management objectives	Evaluation of short- and medium term fleet management with spatial explicit effort allocation for testing the robustness o long term management plans under various fishermen reactions; Biological objectives addressed in multi-species context; Fleet reaction to management can be addressed; Evaluation of biological and economic effects of changing minimum landing size (MLS) for Nephrops compared to the mesh size used in the mixed Nephrops trawl fishery in Kattegat;
Aim: Corresponding advice needed/ addressed	Short and medium term, LTMP, multi-fleet based advice; Partial fishing mortalities by fishery/métier; Stock MSY advice based on multi-species interactions; Effects of changing minimum landing size for Nephrops; Advice aimed towards ICES and EU STECF and National Administrations; Model scientific published and used in scientific research projects; Applied in EU STECF Advice Report on Baltic cod LTMP for the eastern and western Baltic cod stocks in 2011-2012; Applied to advice for minimum landing size for Nephrops in Kattegat 2015-2016.
Institutional Set-up: (Bodies involved, needed partners);	Development, establishment and publication of the model (scientific documentation): university and fisheries research institutes (DTU Aqua and research partners); Model published in scientific journals; Implementation into advice: ICES and EU STECF and National administrations; Applied in EU STECF Advice Report on Baltic cod LTMP in 2011-2012; Applied to advice for minimum landing size for Nephrops in Kattegat 2015-2016.
Type of Model (ecol, econ, soc., long-term, short-term)	Spatial and bio-economic stochastic simulation framework which combines a spatial fishing behavior model at the ICES square resolution to spatial population availability; Short term to medium term scenario evaluation of cod stocks in a multi-fisheries context; Short term to medium term scenario evaluation of Nephrops stocks and fisheries in Kattegat according to change of MLS for Nephrops in IIIa.
Model Dimensions and Model Structure	Multi-stock-multi-fleet: Operating with aggregation of fishing effort by fleets/metiers (e.g. EU DCF metiers). Biological OM on stock level and resource availability informat research surveys. Age based model. Seasonal explicit (quarterly basis) and spatial explicit: Need information on spatio-temporal disaggregation of the fishing

	activities and the resources, basically at the ICES square level.
Usefulness of the Model (Pro, Cons, Problems)	Cons: Calibration. Complex. Data demanding. Can only be operated by a specialist (or the model developers). Pros: Exploitation patterns specific to fleets; Economic outcomes and fishing mortality by fleets. Spatial modeling. For the Baltic coupled to the SMS model accounting for trophic interactions. The model is able to integrate the combined effect of fleet, stock and management dynamics and to project the relative effect of different 'what if' scenarios (via performance metrics) for different management options on TAC, Effort, and or Technical Management Measures (e.g. closures, mesh size change, MLS change, etc.) on a spatial and temporal explicit scale. High level of detail and data information use. Spatio-temporal explicit. Operates with several stocks and fleets (metiers). Integrate technical and biological interactions. Model implicit stock assessment.
Focus and Trade offs	Management Strategy Evaluation framework making use of the FLR libraries dedicated to such evaluations. Account for fleet-specific fisheries behavior scenarios including effort displacement in reaction to closure, technological creeping, and entry/exit dynamics.
Data needed	• Multi-countries STECF/DCF landings (weight and value) and effort data per ICES rectangle • Capacity • Scientific research surveys mapping the resource • Gear specifications (optional) • Stock assessment data • Stomach content data and survey indices for multi-species interactions (Baltic) • Account statistics (or annual variable and fixed cost structure from EU AER)
Data available Used in case study/model	The model has so far been applied by EU STECF to evaluate the consequence of the cod, sprat, and herring interlinked dynamics on the revenues of several fleets within the Eastern Baltic sea; Also used to evaluate consequences of changing the MLS for Nephrops in Kattegat on the Nephrops stocks and fisheries.
Status for application / implementation	Model developed and tested; Model published in international peer reviewed scientific journals; Model applied in advice (EU STECF; ICES);
Model Platform and Programming Language (free, commercial)	Written in the R freeware, making use of the Fishery Libraries in R (FLR). SMS written in C++/AD model Builder.
Model output (format)	Partial fishing mortality by stock, effort, value of catch and profit by fleet. Usual stock indicators (R, F, SSB) calculated on multi-species assessment basis.

Impact Assessment Model for Fisheries Management (IAM)

Case Study / Model	Impact Assessment Model for Fisheries Management (IAM)
Authors / Contact Persons*	Macher, C., Merzéréaud, M., Guyader, O., Bertignac, M., Le Grand, C., Frésard, M., Daurès, F., Fifas, S. claire.macher@ifremer.fr; mathieu.merzereaud@ifremer.fr;
Aim: Management addressed, management objectives	Scenarios of transition to MSY or MEY based on TAC and quotas constraints by fleet (or vessel) or fishing mortality objectives with adjustment of number of vessels by fleet and/or fishing effort (number of days at sea), Analysis of trade-offs and distribution of impacts of scenarios of reduction in fishing mortality proportional to fleets fishing mortality or according to pro rata contribution of fleets to fishing mortality; Harvest Control Rules, variation of the exploitation pattern by métier (with consideration of the survival rate), scenarios of governance of quota: Producer Organization pooling and co-management, centralized management or ITQ Biological objectives MSY, SSB, reduction in discards scenarios with effort reallocation (in progress) Socio-economic objectives: MEY, employment, minimum profit…
Aim: Corresponding advice needed/ addressed	Bio-economic advice, short, medium and long term strategic advice according to reference points (MEY, MSY), analysis of transition phases variation to initial situation, cost-benefit analysis of management options and distribution of impacts between fleets and between owners and crew, socio-economic viability (positive profit) and biological viability (Precautionary approach SSB). Model used for the impact assessment of the Bay of Biscay sole and the SW MAP (Simmonds et al., 2011, STECF, 2015), Model used in partnership approaches with stakeholders to help in definition of the future management plan for the Bay of Biscay, Model used for the ICES workshop on the evaluation of Harvest Control Rules for the Bay of Biscay Sole (use of the biological module); model used in national context for impact assessment of socio-economic consequences of TAC proposed; impact assessment of Mediterranean management plan on gulf of Lions Hake and adequacy of capacity in the scallop fishery in the Bay of St Brieuc (Channel)
Institutional Setup: (Bodies involved, needed partners);	Model developed at IFREMER/ Marine Economics Unit- UMR AMURE since 2009, in the framework of the bio-economic partnership working group project funded by the Directorate of Sea Fisheries and Aquaculture (DSFA). The project brought together fishers representatives (National, Regional and Local Committees of fishermen, Regional Advisory Council, producer organizations...), researchers in biology, economics and sociology, and representatives of DSFA to discuss methods for bio-economic impact assessment for fisheries management decision-support. Methods developed were applied to operational case studies (in the Scallop channel fishery, in the gulf of Lions Hake fishery and in the Bay of Biscay Demersal fishery) to help in decision making. The model was developed, tested and validated in particular in the Bay of Biscay case study to help in decision making. A R package has been implemented. Key developers from Ifremer are still required to develop, implement and run the model however as no training have been organized for instance.
Type of Model (biol, econ, soc., long-term, short-term)	Integrated model, System model, bio-socio-economic model, complex model: multi-species, multi-fleet (or individual vessel model), multi-métier model, represents interactions between resources, usage and governance. The model performs short term, medium and

	long term projections. It is a stochastic model, the model is already able to include uncertainties on a large range of parameters (Recruitment, price, mean weight at age, etc), it is possible to modify slightly the model and add uncertainties to all the input variables if needed. The model can also perform optimisation, both "externally", using available R optimization tools applied to model I/O, or making use of the internal optimization routines implemented in C++ to operate further during the simulation Time step is year or trimester for biological analytical models, and year for economic dynamics and the model is spatially aggregated however, detailed definition of metiers by area and season can enable to address implicit questions of spatial or season management.
Model Dimensions and Model Structure	Dimension: Fleet or vessel, métiers, species, age, with métiers defined as a gear targeting a group of species during one season and in a given fishing area. The model has a modular structure which enables to use modules independently or connected, a module allocates the fishing mortality by stock between vessel or fleet and métiers according to input data, a population dynamics module calculates at each time step the status of the stock, a catch module calculates landings and discards by fleet-vessel, métier and species according to the stock dynamics and options on CPUE for species for which population dynamic is unknown, a market module calculates prices by grade and revenue, an economic module calculates aggregated and dis-aggregated indicators of economic performances of vessels, fleets or fishery, a scenario module enable to implement scenarios and variation in input variables at each time step and on each dimension, a behaviour module describes the effort reallocation behaviours in particular. Optimisations loops are also included to assess reduction in effort or number of days at sea such that MSY objective is reached with 50% probability by 2015 for example.
Usefulness of the Model (Pro, Cons, Problems)	Pro: Operational model that: 1. uses existing input data (DCF transversal and economic data to parameterize fleet-métier and outputs from stock assessment SS3, XSA etc to parameterize stock dynamics); 2. deals automatically with the allocation of the fishing mortality by fleet metier Yearly and spatially aggregated scales enables to address number of management issues concerning management targets or governance of quotas Modular structure and possibility for adapting the model Core implementation of the model in C++, loaded and controlled in R session., combines performances for calculation and optimisation of C++ and user-friendly pre/post-processing tools of R Enables to perform simulations during meetings (ex: Simmonds et al., 2011; HCR sole bay of Biscay 2013) Cons: yearly time step, spatial aggregation + relative complexity and needs for detailed methodology
Focus and Trade offs	Useful model for impact assessment of management scenarios such as: - selectivity scenarios - analysis of trade-offs of transition schemes to reference target (MSY, MEY) - analysis of impacts of options of transition to MSY for the stocks, the fleets and employment (for example based on constant quota scenarios)

	- cost-benefit analysis - analysis of viability and analysis of distribution of impacts between fleets - analysis of impacts of governance scenarios including ITQ. Model developed in particular for the Bay of Biscay in partnership with stakeholders
Data needed	Stock dynamic inputs: classical outputs and inputs from stock assessments (SS3, XSA). Inputs for short term predictions in particular Fleet or vessel data: DCF transversal and economic data used to parameterize fleet-métier + crew share if available Market data: data from transversal DCF data on price per grade or species by default or parameters of price-elasticity relationships if possible to estimate
Data available Used in case study/model	All the input parameters are supposed to be available in the framework of the DCF. The level of aggregation of the DCF is however most of the time not pertinent and simulations would required disaggregated data.
Status for application / implementation	The model was documented in Merzéréaud et al., 2011 and in academic publications and in academic publications (Guillen et al,2013; 2014;2015; Raveau et al.,2012; Macher et al., 2013).. Applications of the model have been developed in the bay of Biscay, the channel scallop fishery and the gulf of Lion Hake fishery. The model is used for expertise and research. It was used in particular for bay of Biscay sole and SW MAP in STECF and ICES. Runs of the model are possible during meetings.
Model Platform and Programming Language (free, commercial)	This model is available through a package for the statistical computing language R. The core of the model is implemented in C++, and is loaded into R as compiled code. Thus, R objects can be passed to this compiled code as model inputs, and model outputs are also made available as R objects. Model package also includes pre and post processing tools to interact/operate with model I/O.
Model output (format)	R output format, Excel export.

283 FishRent Bio-Economic model, North Sea saithe fishery (FISHRENT TI)

Case Study / Model	North Sea saithe fishery FishRent model (FISHRENT TI)
Authors / Contact Persons*	Sarah Simons, sarah.simons@thunen.de
Aim: Management addressed, management objectives	Bio-economic implications of alternative policies (e.g. harvest control rules, area closures) under changes in stock development (e.g. recruitment variability, species distribution) and/or changes in economic pressures (e.g. fish prices, fuel prices)
Aim: Corresponding advice needed/ addressed	Short, medium and long-term multi-stock and multi-fleet model. Biological advice: Median SSB values, probability of SSB being above a certain reference point, forced or stochastic recruitment possible, instantaneous age-specific fishing mortality rates, Socio-economic advice: Fleet size adjustments, Effort allocation in space and time, net profit, net present value, gross value added, crew costs.
Institutional Setup: (Bodies involved, needed partners);	Further developed by the Thünen Institute of Sea Fisheries and LEI. Applied and documented within the FP7 EU Project "VECTORS".
Type of Model (ecol, econ, soc., long-term, short-term)	A multi-species, multi-fleet bio-economic simulation and optimisation model with integrated stochastic age-structured population dynamics. Species seasonal migrations to feeding and spawning grounds are included. Monthly, seasonal or annual time step possible. Short-, medium-, and long-term predictions. Resolved on ICES Rectangle level. The optimisation of net profits determines the effort adjustment and the dis- and investment behaviour of fleet segments, which in turn affect the level of catch rates and discards.
Model Dimensions and Model Structure	Currently five fleet segments from Germany, Denmark, France and England are included in the model. The stock development of North Sea cod and saithe are modeled explicitly. All ICES rectangles of the North Sea and Skagerrak are included and the model runs on a monthly basis. All dimensions can be enlarged or decreased. Current running time ca. 40 min. The model consists of a population dynamics module, an economic (costs and profit), policy (e.g. TAC, area closures), behaviour (dis-/investment), price (fish/fuel) and interface (Catch, discard and landings calculation, effort choice) module.
Usefulness of the Model (Pro, Cons, Problems)	Pros: multidisciplinary tool, multi-species, multi-fleets, monthly, seasonal or annual time step, provides valuable indicators, forced and/or stochastic recruitment can be used to analyse economic response of multiple fleet segments to changes in stock development, strongly integrates economics of the fleet, the impact from fisheries on stock development and their spatio-temporal interplay. Cons: data is needed in the right format, investment function needs to be improved, GAMS licence is needed (but for the future the aim is to re-write the model in R)
Focus and Trade offs	Focus on the strong integration of economic and biological components of the fishery system, without making the model too complex
Data needed	Economic data (capital, fix, variable, crew and fuel costs, fuel consumption), fish and fuel price data, landings weight/value data, spatial data, biological data (maturity, distribution, F, SSB, recruits, TSB), catch-effort data, and management data. Data must be collected in relation to the scenarios.
Data available Used in case study/model	IBTS survey data, ICES assessment data and EU DCF data

Status for application / implementation	Model has been used to re-evaluate the current harvest control rule for North Sea saithe (paper submitted to the ICES Journal). Further developed and applied within the FP7 EU Project VECTORS
Model Platform and Programming Language (free, commercial)	GAMS (license needed), R. There is a web-based version available (http://www3.lei.wur.nl/fishrent/) but with simplified biology, the aim is to re-write the model completely in R to make it freely available
Model output (format)	Catch and effort estimates per month, scenario, fleet segment, species, age class, area; costs, crew wages, revenues, profit gross cash flow and number of vessels per scenario, year, fleet segment; SSB, recruitment estimates per species, month, area; instantaneous fishing mortality rates per species, age class, month, area; probability of SSB being above a certain reference point

Western Waters, FishRent (FISHRENT TI)

Case Study / Model	Western Waters, FishRent (FISHRENT TI)
Authors / Contact Persons*	
Aim: Management addressed, management objectives	Determination of Rent
Aim: Corresponding advice needed/ addressed	Strategic economic advice
Institutional Set-up: (Bodies involved, needed partners);	Internally STEC
Type of Model (ecol, econ, soc., long-term, short-term)	Long term deterministic simulation and optimization
Model Dimension and Model Structure	
Usefulness of the Model (Pro, Cons, Problems)	Pro: Excel Cons: Excel; Biological side simplified (based on biomass, no species interactions); Deterministic
Focus and Trade offs	Different policies as well as systems of collecting rents
Data needed	Biomass by stock, catches prices and costs (on fleet level)
Data available Used in case study/model	From the biological side almost all. From the economic side data looks sufficient but the segmentation of DCR/DCF can cause problems
Status for application / implementation	Final report of the Study on the remuneration of spawning stock biomass: http://ec.europa.eu/fisheries/documentation/studies/-remuneration_of_the_spawning_stock_biomass_en.pdf
Model Platform and Programming Language (free, commercial)	Excel (commercial)
Model Output (Format)	

287 Spatial Integrated bio-economic Model for Fisheries (SIMFISH)

Case Study / Model	North Sea flatfish and shrimp fisheries, SIMFISH
Authors / Contact Persons*	Katell Hamon and Heleen Bartelings, katell.hamon@wur.nl; heleen.bartelings@wur.nl
Aim: Management addressed, management objectives	Impact on fisheries of : - changes of spatial use, - changes of species distribution, - what if simulation of climate change - ITQ management - MEY optimization
Aim: Corresponding advice needed/ addressed	Short, medium multi-stock and multi-fleet model. Socio-economic advice: Fleet size adjustments, Effort allocation in space and time, ITQ management, MEY optimization, net profit, net present value, gross value added, crew costs.
Institutional Setup: (Bodies involved, needed partners);	Initially based on the Excel-based FISHRENT, it was further developed by LEI in cooperation with Thünen Institute of Sea Fisheries. Currently applied and documented within the FP7 EU Projects "VECTORS"," COEXIST", "Myfish", and "SocioEC".
Type of Model (biol, econ, soc., long-term, short-term)	A multi-species, multi-fleet bio-economic simulation and optimisation model with either a global population module or an integrated age-structured population dynamics module. The choice between biological modules can be made based on available data. Monthly, seasonal or annual time step possible. Short-, medium-, and long-term projection. Resolved on ICES Rectangle level. The optimisation of net profits determine s the effort adjustment and the investment and disinvestment behaviour of fleet segments, which in turn affects the level of catch rates and discards. Trading in ITQ's between fleets of a same country or with countries is included. MEY optimization is included.
Model Dimensions and Model Structure	Currently several segments targeting flatfish and shrimp from Netherlands, Germany and England are included in the model explicitly. All ICES rectangles of the North Sea are included and the model runs on a yearly basis. All dimensions can be enlarged or decreased, seasonal catch and prices patterns can be included. The model consists of a biological module , an economic module (costs and profit), policy module (e.g. TAC, area closures), behaviour module (dis-/investment), price module(fish/fuel) and an interface (Catch, discard and landings calculation, effort choice) module.
Usefulness of the Model (Pro, Cons, Problems)	Pros: multidisciplinary tool, multi-species, multi-fleets, monthly, seasonal or annual time step, spatial resolution, provides valuable indicators, can be used to analyse economic response of multiple fleet segments to changes in stock development, strongly integrates economics of the fleet, the impact from fisheries on stock development and their spatio-temporal interplay. Cons: investment function needs to be improved, GAMS licence is needed to run the model, some functionalities require a lot of data
Focus and Trade offs	Focus on the strong integration of economic and biological components of the fishery system, without making the model too complex
Data needed	Economic data (capital, fix, variable, crew and fuel costs, fuel consumption), fish and fuel price data, landings weight/value data, spatial data, biological data (maturity, distribution, M, SSB, recruits), catch-effort data, and management data. Data must be collected in relation to the scenarios.

Data available Used in case study/model	The following data was used: IBTS survey data, ICES assessment data and EU DCF data, Catch and effort data per fishing segment and rectangle
Status for application / implementation	The model was documented in Saltz et al., 2011. Applications of the model have been developed in Coexist (2013), VECTORS (Bartelings et al. 2015), Myfish (Kempf et al. 2016) and SOCIOEC (unpublished).
Model Platform and Programming Language (free, commercial)	Combination of GAMS (commercial), R (free).
Model output (format)	Gdx files, graphs, R-files and SQL database

314 FishRent Bioeconomic Model (FISHRENT IFRO)

Case Study / Model	FishRent Bioeconomic Model (FISHRENT IFRO)
Authors / Contact Persons*	Ayoe Hoff, Hans Frost, ah@foi.dk; hf@foi.dk
Aim: Management addressed, management objectives	Determination of Rent and/or Net Present Value (NPV), given input (effort) and output (quota) management objectives.
Aim: Corresponding advice needed/ addressed	Strategic economic advice: Fishrent can test effects of ITQ and taxes in various formats
Institutional Setup: (Bodies involved, needed partners);	Uses: STECF data Economic data on a national basis
Type of Model (ecol, econ, soc., long-term, short-term)	Bioeconomic model, long-term deterministic simulations and optimization.
Model Dimensions and Model Structure	Includes *x* fleets catching *y* species in a given fishing area. Model built in Excel.
Usefulness of the Model (Pro, Cons, Problems)	Pros: The model is developed in Excel which is easily accessible. The model is currently being made more user friendly with respect to input of data. Cons: The optimisation part of the model can for larger versions (i.e. generally > 4x4) only be run by using the Premium Solver Platform that does not automatically come with Excel. Biological part of the model still under development. Currently biomass based and with simple Schaefer species interactions. Model currently deterministic, with no stochastic module.
Focus and Trade offs	Different policies as well as systems of collecting rents
Data needed	Biomass and yields by stock, historical catch and cost data on fleet level.
Data available Used in case study/model	The biological side: good coverage if stock assessment and recruitment estimates are available, if not the biological dynamics is lost. From the economic side data looks sufficient but the segmentation of DCR/DCF can cause problems, if years before 2007/2008 are included, where the DCF fleet segmentation changed structure.
Status for application / implementation	Model currently (autumn 2013) being changed to a more user friendly version. Species interaction being built into model. Model currently being extended with a bycatch module making it possible to model bycatch of sensitive species.
Model Platform and Programming Language (free, commercial)	Excel Premium Solver Platform for Excel (commercial add-in)
Model output (format)	Excel tables

Swedish Resource Rent Model for the Commercial Fisheries (SRRMCF)

Case Study / Model	Swedish Resource Rent Model for the Commercial Fishery (SRRMCF)
Authors / Contact Persons*	Staffan Waldo (staffan.waldo@slu.se) Anton Paulrud (anton.paulrud@havochvatten.se)
Aim: Management addressed, management objectives	The aim of the model is to give economic advice on intended management actions. These could be economic, technical or biological.
Aim: Corresponding advice needed/ addressed	Example of indicators: Economic performance, effort (total and per ICES area), fleet size, fleet structure (vessels per segment), employment, quota utilization, type of gear used.
Institutional Set-up: (Bodies involved, needed partners);	AgriFood Economics Centre at the Swedish University of Agricultural Sciences (SLU) Swedish Agency for Marine and Water Management Department of Aquatic Resources, SLU
Type of Model (ecol, econ, soc., long-term, short-term)	Economic optimization model that provides the optimal fleet structure given quotas and technical regulations. The model is static and used for comparing outcome in baseline and a modelled situation with changed regulations.
Model Dimensions and Model Structure	The model is implemented for Swedish fisheries, but can be extended to other countries. 10 fleet segments are included based on vessel length, gear, and target species. 180 métiers and 40 species, 12 fishing seasons (months) and ICES areas II and IV (Baltic Sea, North Sea, Kattegat and Skagerrack) are included.
Usefulness of the Model (Pro, Cons, Problems)	Detailed analysis of the fleet but only static (with possibility to repeat analysis for several years).
Focus and Trade offs	The number of dimensions (fleets, species, etc.) is large which is possible since the model is static and thus do not model the development and interaction over time. The dimensions will, however, interact in order to find the model solution. Focus in the model is on economic and social aspects given a fixed biological frame defined by catch quotas.
Data needed	Landings, effort, costs and prices by métiers Economic data by fleet segment
Data available Used in case study/model	All data is from DCF
Status for application / implementation	The model has been used for management advice regarding: Introduction of ITQs in Swedish fisheries (Waldo and Paulrud, 2013) Economic consequences of sprat reduction in the Baltic Sea (not published yet) Impact of Abolishing Fuel Tax Concessions in Nordic Fisheries (not published yet)
Model Platform and Programming Language (free, commercial)	GAMS (General Algebraic Modeling System) combined with Excel
Model output (format)	Excel sheet

318 New England Coupled Lobster Model (NECLH)

Case Study / Model	A coupled model of the lobster and herring fisheries in New England (NECLH)
Authors / Contact Persons*	Sigrid Lehuta, Daniel S. Holland, Andrew J. Pershing Contact: dan.holland@noaa.gov; sigrid.lehuta@ifremer.fr
Aim: Management addressed, management objectives	This model is aimed at providing advice to managers and stakeholders in the both the lobster and herring fisheries in New England. It provides predictions of how changes in management or recruitment in either fishery affects both fisheries.
Aim: Corresponding advice needed/ addressed	The simulations track a large number of variables but we report a more limited set of 11 outputs that are most relevant from a policy standpoint. These include the number of boats involved in the lobster fishery, total economic profit, total opportunity costs of captains' time, total crew wages, wages of a single crew member per day in the lobster fishery, lobster biomass and catch, biomass of Gulf of Maine and Georges Bank herring stocks, total herring catch, and the amount of substitute bait used. Other outputs such as prices, herring TACs, catch of herring per area and stock are tracked and analyzed to provide a better understanding of the processes but are not reported here. All reported outputs reflect values for the final year (year 20) of the simulation. The model runs on a monthly time step and also provides information for all outputs on a monthly basis.
Institutional Setup: (Bodies involved, needed partners);	The modeling work was done under a grant awarded to the Gulf of Maine Research Institute and the University of Maine by the US National Science Foundation. Data and advice were provided by NOAA and the Maine Department of Marine Resources.
Type of Model (ecol, econ, soc., long-term, short-term)	The model is a bioeconomic simulation model focused on long-term outcomes. Model results are produced for year twenty, however, since the model is deterministic, the annual results have generally stabilized after only five years.
Model Dimensions and Model Structure	The model domain for the lobster model is focused on the Maine lobster fisher in the Gulf of Maine and is not explicitly non-spatial. The herring model that is linked to the lobster model covers a more extensive domain divided into four areas to represent the four current management areas for herring. Seasonal migrations of herring substocks between these areas were models as well as area-specific catch. The biological model for lobster is size structured while the herring model is age-structured. Both models run on a monthly time step. The lobster and herring models are linked through the market for lobster bait. The quantity of bait demanded by the lobster fishery is determined endogenously by the model and it is provided by the herring fishery in the least cost manner unless cost it too high or availability limited in which case the lobster fishery is assumed to satisfy residual bait needs with menhaden. This would be small part of Menhaden production and that fishery is not modeled.
Usefulness of the Model (Pro, Cons, Problems)	The model combines existing information, individually validated models, and empirical analyses, to build a coupled model of the lobster fishery in Maine and Northeast US herring fishery. Each module makes use of parameters and data also employed in assessment models, and is defined at an appropriate scale that matches the scale of the assessment model or the scale at which regulation is implemented. This increases the transparency and credibility of the model and transferability of its results to management decisions. As a consequence, the full model structure is

Focus and Trade offs	The focus of the model in on the linkage between the two fisheries that results from the fact that herring is the primary bait for the lobster fishery and the lobster bait market is the primary source of demand for the herring. While fairly complex, the model does not consider linkages between these fisheries and other parts of the ecosystem (e.g prey or predators of either species). However, single-species models connected through the important natural and human linkages offer a fruitful middle ground to ecosystem models. Such models can provide advice at a scale that is directly comparable to that provided by the single-species models currently used to inform management decisions. The linked models can clarify the role that connections with other fisheries and the environment play in altering expected outcomes and management advice relative to that based on current single-species models.
Data needed	Parameterizing the model was done partly by adopting existing stock assessment models for the biological models. However, price and costs data and production data (e.g. catch per day and input use) were required to parameterize economic models. This includes data from cost-earnings surveys, observer data, landings data and port sampling data of lobster.
Data available Used in case study/model	Sufficient data was available and was used in the model.
Status for application / implementation	The model development is complete and a publication with results from several scenarios is forthcoming in CJFAS
Model Platform and Programming Language (free, commercial)	R
Model output (format)	Text, CSV other R output and figures

Baltic Sea Ecological-Economic Optimization Model (BALTIC ECON-ECOL)

Case Study / Model	Baltic Sea ecological-economic optimization model (BALTIC ECON-ECOL)
Authors / Contact Persons*	Martin Quaas*, quaas@economics.uni-kiel.de, Rudi Voss, voss@economics.uni-kiel.de, Jörn Schmidt, jschmidt@economics.uni-kiel.de
Aim: Management addressed, management objectives	Optimal net revenue under consideration of species interactions, age structure and environmental sensitive stock-recruit relationships
Aim: Corresponding advice needed/ addressed	Strategic medium to long term advice for total harvest of single species, multi-age classes; gives variable F for transition period until steady state, avoids negative revenues
Institutional Setup: (Bodies involved, needed partners);	Used in academic context; builds on standard assessment from ICES with respect to age structure of the species under consideration and for input data; uses functional relationships from stochastic multi-species model (SMS) developed by DTU-Aqua
Type of Model (ecol, econ, soc., long-term, short-term)	Ecological-economic optimization model Medium to long-term
Model Dimensions and Model Structure	Considers whole fisheries and stocks; at the moment the model covers eastern Baltic cod, Baltic sprat and Central Baltic herring
Usefulness of the Model (Pro, Cons, Problems)	The model consists of functional relationships and a limited number of input parameter and is thus easy to understand and to apply. The model does not resolve fleets or metiers and assumes optimal effort allocation and constant costs and price over time
Focus and Trade offs	The model shows the effect of species interactions on the optimal harvest of a given species, e.g. optimal sprat harvest under different cod management scenarios.
Data needed	Stock assessment data, costs, prices and stock-recruit relationships. The latter can also be dependent on temperature or salinity or other environmental variables.
Data available Used in case study/model	For the Baltic case study all necessary data is available; improvement can be made with respect to environmental sensitive S/R-relationships and functional relationships of species interactions
Status for application / implementation	The model is currently in use for different studies on Baltic fisheries, partly published
Model Platform and Programming Language (free, commercial)	Matlab (commercial) with KNITRO solver (commercial);
Model output (Format)	Matlab vectors and matrices, raw txt data

339 Effects of Line Fishing Simulator (ELFSIM)

Case Study / Model	The Effects of Line fishing Simulator (ELFSIM)
Authors / Contact Persons*	Rich Little (Rich.Little@csiro.au) , Bruce Mapstone (Bruce.Mapstone@csiro.au)
Aim: Management addressed, management objectives	A spatially explicit model used to evaluate fisheries management options including marine reserves, as well as ITQs, monitoring programs and assessment procedures on the Great Barrier Reef of Australia, in terms of industry, conservation and social-economic objectives.
Aim: Corresponding advice needed/ addressed	The required advice has been: 1. What are the effects on the fishery of additional marine closures? 2. What are the effects on the fishery of changes in effort? 3. What are the effects on the fishery of an ITQ system? 4. Can a stock assessment accurately estimate the biomass of such a spatially complex population? 5. What data are needed to accurately estimate the stock abundance?
Institutional Setup: (Bodies involved, needed partners);	1. NGOs including WWF. 2. Australian government conservation agency: Great Barrier Reef Marine Park Authority 3. State of Queensland fisheries management agency (Fisheries Queensland) 4. Industry association: Queensland seafood industry association 5. Recreational fishing representatives. 6. Charter fishing representatives. 7. Quota holders association.
Type of Model (ecol, econ, soc., long-term, short-term)	Simulation of multi-species (coral trout, red-throat emperor) metapopulation model, with an agent-based fishing dynamics model coupled to a ITQ market model and a management model component.
Model Dimensions and Model Structure	Regional model of age-, size structured, spatially explicit (>3000 sub-populations) connected through hydrodynamic larval advection. Three fleets (commercial, charter and recreational fishing). Operates at a monthly time scale.
Usefulness of the Model (Pro, Cons, Problems)	Management strategy evaluation. Provides a central point of discussion over fisheries management objectives in an environment of contested values. Does not represent the broader ecosystem or biodiversity.
Focus and Trade offs	
Data needed	Historical catch and effort data by fleet at the reef and month level. Standard biological parameters for growth etc. Economic data for fishing vessels, particularly cost of operations and fish prices.
Data available Used in case study/model	Recreational fishing data at the spatial and time scale is strongly lacking. We have recently done an economic survey of the commercial fleet to measure the vessel operator economic data.
Status for application / implementation	Operationally used for providing fisheries management advice on the GBR and are in the process of transferring the operational capacity to fishing management agency.

Model Platform and Programming Language (free, commercial)	Language: Originally: visualBasic with MS C++ DLL Current: ANSI C with some MFC which are being phased out.
Model output (format)	Data output: MS Access Data output: basic KML output functions for Google Earth maps Data input : MS Access

Australia Northern Prawn Fishery Tiger Prawns Bio-economic Model (NPFTPBEM)

Case Study / Model	Australia Northern Prawn Fishery (NPF) / Tiger Prawn Bio-economic Model (NPFTPBEM)
Authors / Contact Persons*	*Cathy Dichmont (cathy.dichmont@csiro.au) Punt Andre (andre.punt@csiro.au) *Rik Buckworh (rik.buckworth@csiro.au) *Roy Deng (roy.deng@csiro.au)
Aim: Management addressed, management objectives	Assess the target species biomass status with respect to sustainability and provide target values for the TAE control, to ensure the fishery is managed under the objective of maximum economic yield
Aim: Corresponding advice needed/ addressed	Target species stock status indicators, MEY optimisation, effort levels required to achieve Target Reference Point (MEY) and hence to provide Total Allowable Effort recommendations.
Institutional Setup: (Bodies involved, needed partners);	CSIRO, Australian Fisheries Management Authority, Northern Prawn Fishery Industry Pty Ltd.
Type of Model (ecol, econ, soc., long-term, short-term)	Biological model to estimate target species' recruitment indices and recruitment index – spawning biomass index relationship parameters. Bio-economic model to optimize the long-term net present value to derive MEY, and effort targets for the short and medium-term management advice
Model Dimensions and Model Structure	Model is designed for multi-fleets, multi-species, multi-stocks and multi-seasons. It is flexible to the richness of the data, i.e., with the options of age-structured and size-structured models. The model consists of a population dynamics model and bio-economic components
Usefulness of the Model (Pro, Cons, Problems)	Pros: provides sufficient information for the fishery's management, fully using all data available including catch and effort data from logbooks and species, sex and length frequency information from fishery independent surveys. Cons: data intensive, computing-intensive, large team required to address separate components
Focus and Trade offs	Focus is on the tiger prawn fishery rather than the banana prawn fishery components of the NPF (similar value, fished by the same fleet). Banana prawn presently does not have an assessment due to highly variable recruitment.
Data needed	Catch, effort, abundance indices, size composition, plus a large amount of input information (species composition predicted by time and location, catchability, natural mortality rate)
Data available Used in case study/model	Catch/effort data from AFMA logbook, survey and commercial abundance indices and size, prior biological information
Status for application / implementation	Standard stock assessment model for the Australian NPF tiger prawn fishery and used in MSE tests.
Model Platform and Programming Language (free, commercial)	Windows and Mac. Model written in ADMB and FORTRAN. ADMB is free. FORTRAN is available as either commercial or free implementations.
Model output (format)	Flat text files which are processed using R to produce summaries in tabular or graphical formats

NPF Simplified Bio-Economic Model for the Australian Northern Prawn Fishery (NPF BIOECON)

Case Study / Model	Simplified Bio-Economic Model for the Australian Northern Prawn Fishery (NPF BIOECON)
Authors / Contact Persons*	Sophie Gourguet and Olivier Thébaud Contact: sophie.gourguet@ifremer.fr; Olivier.Thebaud@ifremer.fr
Aim: Management addressed, management objectives	This bio-economic model is aimed at synthesizing in a single simplified model, previous modelling works by Dichmont et al. (2003, 2008) and Punt et al. (2010, 2011) on the NPF, and extending it by integrating the more variable banana prawn resource in order to examine co-viability conditions for the fishery. The NPF fishery consists of two main sub-fisheries: a banana prawn sub-fishery, which is a single-species fishery targeting the white banana prawn (*Penaeus merguiensis*), and a tiger prawn sub-fishery, which is a mixed species fishery targeting grooved and brown tiger prawns (*Penaeus semisulcatus* and *Penaeus esculentus*, respectively), as well as blue endeavor prawns (*Metapenaeus endeavouri*), caught as byproduct. One of the aims of this multi-species bioeconomic and stochastic model is to account for the interactions between tiger and banana prawn sub-fisheries and thus be able to examine the trade-offs between mean profitability of the fishery and its variance, under a range of economic scenarios, fishing capacities and distributions of fishing effort across the various sub-fisheries that comprise the NPF. A mean-variance analysis is used to examine the tradeoffs. Furthermore, an application of a stochastic co-viability framework to this model allows to assess the ability of fishing management strategies to meet multiple constraints imposed on the fishery. Management strategies can differ, for instance, in the number of vessels involved across the fishery, and are evaluated under different effort combination scenarios describing the proportion of effort allocated to the tiger prawn sub-fishery.
Aim: Corresponding advice needed/ addressed	The simulations track various variables such as economic profit and net present values for both sub-fisheries and the overall fishery, spawning stock indices for tiger and endeavour prawns, catches for tiger, endeavour and banana prawns, and catches of seasnakes (used as en ecological indicator of trawling impacts). Outputs are reported accounting for the stochastic nature of the model (i.e. environmental variabilities that are applied to annual recruitment of tiger and blue endeavour prawns and to white banana prawn annual biomasses). The model runs on a weekly time step and provides information for the outputs on a weekly and/or annual basis.
Institutional Setup: (Bodies involved, needed partners);	The modeling work was done under a project financed by the French National Research Agency (ANR) project ADHOC. Data and advice were provided by CSIRO and the Wealth from Oceans Flagship.
Type of Model (ecol, econ, soc., long-term, short-term)	The model is a bioecomic simulation model. Model results are produced for ten years. However, the model can produce results for any time horizon.
Model Dimensions and Model Structure	The model is focused on the NPF in the Gulf of Carpentaria in Australia and is not explicitly spatial. Population dynamics of tiger and blue endeavour prawns are based on a multi-species weekly time-step, sex-structured population model with Ricker stock-recruitment relationship and environmental uncertainties. The population dy-

	namics model allows for week-specificity in recruitment, spawning, availability and fishing mortality. However, white banana prawns are represented without explicit density dependence mechanisms, due to highly variable recruitment and absence of a defined stock–recruitment relationship. The model is stochastic (i.e. environmental variabilities are applied to annual recruitments of tiger and blue endeavour prawns and to white banana prawn annual biomasses). The two tiger and banana sub-fisheries are explicitly linked through an effort allocation model.
Usefulness of the Model (Pro, Cons, Problems)	The model combines the understanding from existing operational models to build a simplified model of the Northern Prawn Fishery including both tiger and banana sub-fisheries. This increases the capability to study the economic trade-offs when targeting an unpredictable naturally fluctuating resource, and a more predictable resource less fluctuating resource. The application of a stochastic co-viability framework allows identification of viable management strategies, in terms of biological, ecological and economic management objectives.
Focus and Trade offs	Trade offs between mean and variance of the profitability of the NPF, associated to decision regarding the capacity and effort of the fleet, given an effort allocation pattern, are analysed. This model also proposes an analytical framework to formally assess the trade-offs associated with balancing biological, economic and biodiversity conservation objectives in a viability sense.
Data needed	Parameterizing the model was done partly by using outputs of existing stock assessment models from CSIRO, as well as economic data provided by CSIRO. Parameterizing the effort allocation model was done from historical data on catches and effort.
Data available Used in case study/model	Sufficient data was available and was used in the model. However, data on thresholds for viability analyses are missing.
Status for application / implementation	The model development is complete. Results focused on balancing bio-economic risks and high profit expectations are published in Ecological Economics, and results from co-viability analyses are under review. Further work can be done on indicators and associated thresholds for viability analyses.
Model Platform and Programming Language (free, commercial)	Scilab (free)
Model output (format)	Excel tables, csv, texts and figures

383 Mediterranean Fisheries Simulation Tool (MEFISTO)

Case Study / Model	MEditerranean FIsheries Simulation Tool (MEFISTO).
Authors / Contact Persons*	Francesc Maynou maynouf@icm.csic.es Jordi Guillén jordiguillen@hotmail.com Jordi Lleonart lleonart@icm.csic.es
Aim: Management addressed, management objectives	Examine the effects on fisheries landings, economic performance of fishing vessels, fisheries rent extraction and stock biomass under alternative management conditions of the fishery based on simulating forward in time the conditions of the fishery. In a multispecies, multigear/multimétier/multifleet context.
Aim: Corresponding advice needed/ addressed	Advice on the likely evolution of the fishery under alternative management scenarios. Alternatives include input management measures: fishing effort (limitation to days per year or hours per day), changes in fleet composition (entry/exit of vessels), and changes in technical measures (i.e. selectivity, catchability). Additionally, the effect of changes in the economic situation can also be assessed: fuel price; fish imports; subsidies to the fleet; exogenous modifications to fish prices
Institutional Set-up: (Bodies involved, needed partners);	Developed at the Marine Science Institute of Spain's National Research Council (CSIC-ICM). Uses data generated by specific research projects, but can also employ parameter estimates derived from official data sources (STECF - DCF)
Type of Model (ecol, econ, soc., long-term, short-term)	Bioeconomic model based on stochastic simulation; short and long-term. Multispecies, multigear/multifleet
Model Dimensions and Model Structure	Arbitrary number of fleets and species. It also allows to set technical (not-biological) interactions between species. Arbitrary number of years of simulation and number of stochastic iterations (in practice, limited by computer capacity)
Usefulness of the Model (Pro, Cons, Problems)	Pros: The model is programmed in Python 2.7 with a user friendly interface and is fully documented. Runs on all Windows versions (native or emulated). Specifically tailored for Mediterranean fisheries, hence it includes most management strategies relevant to fisheries managed through input control (no TACs) The number of output indicators is relatively large (13 biological, technical or economic indicators) but should be enlarged to include indicators and plots for use of fisheries managers. Output indicators and charts can be exported to other programs for further manipulation (e.g. MS Excel, Word...) Cons: The model runs at annual scale and outcomes are reported accordingly. Management measures based on temporal closures, for instance, cannot be directly simulated, even if they could be approximated. Spatial dimension is absent. No optimisation algorithms, no TAC-based management simulation.
Focus and Trade offs	The focus is on simulating traditional alternative management strategies for Mediterranean fisheries (effort-based control; selectivity; entry/exit) and to assess the effect of changes in the economic conditions (fuel price, fish price, fish imports, fish subsidy). The model is focused on this and is very easy to operate under this conditions; as a trade-off it is difficult or impossible to test management measures not foreseen (for instance, spatial dimension of fisheries management).
Data needed	For each target species of the fishery: growth parameters; natural mortality; maturity ogive; number of individuals and fishing mortality at the start of the simulation, and, optionally, parameters of a

	stock-recruitment function For each fleet in the fishery: number of boats; general costs of the fleet and specific costs of individual vessels (or average per vessel in a fleet) For each species: average price per species; however, it is recommended to use parameters of the price function by species per fleet. Data can be uploaded using Excel tables.
Data available Used in case study/model	The model is parameterised from biological and economic data obtained from specific research projects, although STECF and DCF data can also be used after specific data analysis
Status for application / implementation	Model fully functional. Executable for Windows can be downloaded and used at no cost to the user from http://www.mefisto.info Current developments aim at discretising the temporal dimension of the simulation engine
Model Platform and Programming Language (free, commercial)	MEFISTO 4.0 (latest build February 2017) Programmed in Python 2.7, free.
Model output (format)	Excel tables and graphs in png format

406 FLBEIA

Case Study / Model	Western Waters FLBEIA
Authors / Contact Persons*	Dorleta Garcia, Sonia Sanchez, Raul Prellezo, Agurtzane Urtizberea, Marga Andrés, dgarcia@azti.es, ssanchez@azti.es, rprellezo@azti.es, aurtizberea@azti.es, mandres@azti.es
Aim: Management addressed, management objectives	The main aim of the tool is to facilitate the evaluation of Multiannual Management Plans. Besides the HCRs associated to the management plans, other management tools such as temporal closures, technical changes and spatial closures (implicitly) may be also evaluated.
Aim: Corresponding advice needed/ addressed	The performance of the HCR is evaluated in bio-economic terms. However, the advice within the MSE simulation is biological (the HCRs are TAC based). If bio-economic HCR were available they could be coded and tested within FLBEIA but at present the use of HCR with economic objectives or constrains is very limited or inexistent.
Institutional Setup: (Bodies involved, needed partners);	FLBEIA has been thought to be used as a tool to facilitate participatory modelling. The aim is to involve stakeholders and managers in the conditioning of the case studies and in the definition of management strategies to be tested. However, it depends mainly on the case study.
Type of Model (ecol, econ, soc., long-term, short-term)	FLBEIA is a fully coupled bio-economic model. The link between biological and economic components is done through the effort and the catch. And the link between the management and economic components is done through the implementation model integrated in the short term dynamics of the fleets. Both short term (tactic) and long term (strategic) dynamics are considered. Short term dynamics run in a seasonal basis and long term dynamics annually. In case specific implementations the model can be very simple, just single stock biological model, or very complex with several stocks, several fleets and metiers and with short and long term dynamics.
Model Dimensions and Model Structure	It is a multistock, multifleet and multimetier simulation agent based model. Time steps can vary from year to any smaller fraction (quarter, month, day…) and the length of seasons can vary within seasons. It is stochastic and the stochasticity is introduced using Monte Carlo simulation. It has a covariates component used to introduced into the simulation variables of interest not taken into account in stock and fleet components (environmental, social or other kind of variables). The stocks can be age structured or aggregated in biomass. The management advice is given annually but the management season can vary between stocks, this was specially designed for bay of Biscay anchovy which management is given in June. The HCR can be model or survey based.
Usefulness of the Model (Pro, Cons, Problems)	The primary use of the model is the implementation of bio-economic impact assessment of fisheries management strategies. It can be applied in a wide range of case studies and management strategies. The main disadvantage is the conditioning of the model that can be very time consuming in the case of complex case studies with many stocks, fleets, metiers and seasons. But this is something common to all complex models with many dimensions, it is not a particular problem of FLBEIA. Related to the complexity of the model is the running time which increases with model complexity. To overcome this problem we run it in parallel in a grid system.
Focus and Trade	The main focus of the model is the evaluation of multiannual man-

offs	agement plans. The traditional HCR can be combined with additional management tools such as temporal closures, technical changes and spatial closures (implicitly) may be also evaluated. The model runs under an MSE framework and allows introducing into the evaluation the main sources of uncertainty inherent to the fishery system, including uncertainty in real system and in the management process. The model is oriented to help in the decision making process, in particular to help managers to define management strategies. However it can also be useful in scientific work. A problem in the use of FLBEIA by non experts is that it runs in R and not all the potential users are fluent using it. We have developed a 'smart' conditioning script that facilitates the use of the model to non R/FLR experts. In the short term it is planned to work in an interface that facilitates the analysis of the results to non-experts.
Data needed	The data needed depends on the complexity of the case study. In the most simple form the stock assessment data should be enough, but clearly this will not include any economics. To include fleets short term dynamics at least the effort in some historical years is needed. Variable cost per unit of effort and fixed cost per unit of capacity are needed to calculate the most simple economic indicators. To include long term dynamics of the fleet fuel costs, crew costs and capital costs are needed. In the biological component the stock recruitment relationship in age structured stocks or the population growth parameters in biomass dynamic stocks must be estimated externally. If the Cobb-Douglas parameters are not estimated externally in the 'smart' conditioning, it is assumed that the elasticity parameters are equal to 1, and the catchability is calculated dividing historical effort by historical biomass.
Data available Used in case study/model	Stock data is generally available through stock assessment working groups, the problem arise when the stock is not analytically assessed. The problem with economic data is that it is not publicly available at metier level and must be collected from sources other than the DCF.
Status for application / implementation	The model is ready to use and there is moderated documentation available. It has been used in European projects and for scientific purposes and in STECF working groups to evaluate multiannual management plans. t was used in the biological evaluation of long term management plans for Anchovy. In 2015 it was used in the bio-economic evaluation of multiannual plans by the STECF in the Iberian Waters, the Bay of Biscay and Celtic and Irish Seas. In all the case studies direct application of the CFP on both stocks and fleets was evaluated. In particular, it was evaluated the impact of the landing obligation policy under different fishing mortality targets.
Model Platform and Programming Language (free, commercial)	R/FLR Free.
Model output (format)	R/FLR and excel (The excel output is not complete, just the main indicators at stock, fleet and metier level).

Fleets and Fisheries Forecast for North Sea demersal fishery (FCUBE, FCUBE ECON)

Case Study / Model	Fleets and Fisheries Forecast (FCUBE, FCUBE ECON in FLR). FCUBE – mainly used for the North Sea demersal fisheries, but applications to other ICES areas have been developed (Iberian waters, Celtic Sea, West of Scotland, Eastern Mediterranean)
Authors / Contact Persons*	Clara Ulrich*, clu@aqua.dtu.dk
Aim: Management addressed, management objectives	Fleet and metier based forecast, tailored to providing mixed-fisheries considerations to the annual ICES single-stock TAC advice. Can also be translated into effort quota, as effort is one input. Suitable for catch quotas and discards ban scenarios. Can be used to help designing flexible Harvest Control Rules to avoid conflicting single-stock management objectives.
Aim: Corresponding advice needed/ addressed	The initial focus and use has been on biological short/medium-term advice through scenarios simulation. In 2015, a medium-term economic impact assessment and an optimisation module have been plugged in. The development of Fcube has been rooted the actual regional fisheries management and advice for the North Sea since 2006. It has been built as an overall flexible framework that has been constantly evolving following management questions and needs.
Institutional Set-up: (Bodies involved, needed partners);	Used by ICES since 2009 as part of annual advice and for ad-hoc mixed-fisheries requests. Used by STECF for evaluating the cod management plan in 2011, and for evaluating the demersal mixed-fisheries management plan in 2015. Much work done in integrating the model together with annual data updates in the DCF frame, and improving the reliability and consistency of data time series (leading to ICES data call merging data needs for both single-stock and mixed-fisheries advice since 2012) . Model integrated within several EU projects (FP 6 AFRAME, EFIMAS, CEVIS, FP7 MYFISH and SOCIOEC, H2020 DiscardLess).
Type of Model (biol, econ, soc., long-term, short-term)	Fcube estimates catch potentials for distinct fleets and metiers based on traditional catch and effort information, thus estimating the potentials for single species TAC under- or over-shoots. Initially biological deterministic short-term forecast, reproducing and building on ICES single-stock advice. Modularly extended towards stochastic medium-term simulations (single-species MSE linked with Fcube as implementation error through over/under quota catches) and economic impact assessment. Flexibility to add any user-defined parameter uncertainty in the script (e.g. catchability)
Model Dimensions and Model Structure	Annual and non-spatial. Unlimited number of fleets, metiers and stocks. All implemented in R/FLR scripts and functions.
Usefulness of the Model (Pro, Cons, Problems)	Pros : Simple principles applied, simple scripts to understand and use, standard computational power. modular and flexible R code, that has adapted to ongoing issues. Used within the current advisory system and known by clients and stakeholders. Integrated with annual data updates within ICES/STECF data calls. Full coherence between fleet data and stock data using ICES data calls and InterCatch DB. Does not rely on many assumptions beyond those usual in short-term forecast. Cons : by not including fishermen behaviour assumptions, the model is not suitable for long-term analysis. Not spatially explicit.

	Scripts rather than stand alone software, that needs user knowledge.
Focus and Trade offs	Fleet and metier based multi-stock management, as opposed to single species management. No a priori assumption on fishermen behaviour, but such module could be plugged in the script if available for the case study (e.g. RUM-based changes in effort allocation across metiers etc). No individual analysis, but specific vessels with specific fishing patterns can be addressed through specific fleets segments (e.g. Fully Documented Fleets in the North Sea)
Data needed	Standard international datasets : Single stock assessment and advice, but can be also adapted to stocks without analytical assessment. Fleet and metier catch and effort data as available from e.g. ICES InterCatch, STECF databases or directly from national institutes. DCF Economic data
Data available Used in case study/model	Much focus on integrating the model with its data flow and improving data availability and consistency. North Sea demersal as primary case study (stocks assessed within ICES WGNSSK plus some bycatch species). Used for West of Scotland, Celtic Sea and Iberian Waters from 2014. Trials in the Mediterranean Sea.
Status for application / implementation	Beyond its current use, the model and its data flow are being continuously developed to address further issues, such as medium-term projections, economic impact assessment, optimisation and inclusions of new areas and species
Model Platform and Programming Language (free, commercial)	R and FLR, free, open source and plate-form independent. Can be then linked and integrated in any FLR modelling.
Model output (format)	Outputs mainly stored as FLStocks and FLFleets objects plus additional R arrays and data frames, that can be easily summarised and plotted afterwards, or integrated in other framework. Additional outputs of model computations can be easily provided.

428 Coupled Georges Bank Food Web and CGE Model (GBFWCGE)

Case Study / Model	Coupled Georges Bank Food Web and Computable General Equilibrium Model (GBFWCGE)
Authors / Contact Persons*	Eric Thunberg*, Eric.Thunberg@noaa.gov
Aim: Management addressed, management objectives	Understanding the economic implications of changes in ecosystem states.
Aim: Corresponding advice needed/ addressed	Integrated ecosystem assessment, Strategic long-term advice on trade-offs in ecosystem uses and services, Understanding future impacts of climate change on system
Institutional Setup: (Bodies involved, needed partners);	Partnership between NOAA Fisheries and the Marine Policy Center of the Woods Hole Oceanographic Institute
Type of Model (ecol, econ, soc., long-term, short-term)	Donor controled food web model based on Steele et al. (2007) of the Georges Banks food web. Computable general equilibrium model of the New England regional economy. Models are run separately by first estimating fishery production through simulation of ecosystem states. The economic value of the resulting changes in fishery production are estimated by solving for market clearing prices using the CGE model.
Model Dimension and Model Structure	
Usefulness of the Model (Pro, Cons, Problems)	Computable general equilibrium models belong to a class of regional economic models. CGE models are an abstraction of a regional economy through estimation of a system of supply and demand equations. The impact of changes in fishery production is derived by solving the CGE model for market clearing prices. Since the model uses a system of supply and demand equations that resulting economic impacts measure the changes in consumer and producer surplus. CGE models are complex and require data that may not be readily available. The major advantage to CGE is the ability to model economic adjustments. This means that some consideration needs to be given to whether a policy change would have a substantial long term impact on a regional economy before investing the time and effort into developing a CGE model. It is likely that CGE models will be most useful in addressing fundamental changes in ecosystem states and not as useful in examining small to modest near term changes in fishery management policy. CGE models are based largely on market transactions. This means that embedded externalities will be reflected in the model. Similarly, non-market values for ecosystem services will not be reflected in the model.
Focus and Trade offs	Focus is on linkages between ecosystem states and regional economies. Both food web and CGE models, by necessity are an abstraction of the natural and economic systems. As such they may not be well suited to evaluate management concerns on a species-specific or at a fishing fleet level. Best use may be to inform long term questions such as the implications of climate change.
Data needed	CGE models require data on purchases and sales between industrial sectors of an economy. In most countries these data are derived from

	National income accounts. If a model is to be developed on a finer regional scale then primary data collection may be required.
Data available Used in case study/model	Data to construct the CGE model of the New England economy were purchased through Minnesota IMPLAN group. These data include an accounting matrix of purchases and sales between over 500 sectors. These data were aggregated into fewer sectors to make the model more tractable.
Status for application / implementation	Model is operational for some applications but is still under development. Emphasis is to be placed on refining the model to include fishing sectors by gears and to include a broader set of human uses of the marine ecosystem such as recreational fishing, tourism, etc.
Model Platform and Programming Language (free, commercial)	
Model Output (Format)	

453 Southeast Australia Atlantis (SEAUS ATL)

Case Study / Model	The Southeast Australia Atlantis (SEAUS ATL)
Authors / Contact Persons*	Beth Fulton (beth.fulton@csiro.au), Ingrid van Putten (Ingrid.Vanputten@csiro.au), Rebecca Gorton (bec.gorton@csiro.au)
Aim: Management addressed, management objectives	Understanding the options for ecosystem based fisheries management in southeast Australia; considering tradeoffs and with triple bottom line (ecological, economic and social) objectives. Strategies considered include, gear restrictions, spatial management, seasonal closures, quota management, discard minimisation or bans, degree of observer coverage. The explorations are done for the now-state as well as under global change.
Aim: Corresponding advice needed/ addressed	The model is used to provide strategic advice around medium to long term management options to the stakeholders and advisory groups involved in the co-management of the Southern and Eastern Scalefish and Shark Fishery (SESSF). It is not for short term tactical decision making (e.g. quota setting); although it has been used to check the robustness (in an ecosystem context) of the quota levels of some key ecosystem components. Model results include spatially specific as well as stock level biomass estimates (for all functional groups in the model), as well as ecological indicators, catches, discards, metier-level economic indicators, simple social indices (e.g. happiness index) and costs of management.
Institutional Setup: (Bodies involved, needed partners);	Model developer and implementation: EA. Fulton, CSIRO Mar. Res., Hobart, (AUS). The work has been primarily funded by the CSIRO and the Australian Fisheries Research and Development Corporation.
Type of Model (biol, econ, soc., long-term, short-term)	Whole of system (End-2-End) system model with full biogeochemical nutrient closure, age and size structured food web (using a combination of functional groups and key species), environmental forcing (hydrodynamic transport module), habitats, metier based effort dynamics module (with effort maps determined by sub-category based on vessel size and operating characteristics using quasi-ABM approach), assessment and fisheries management module and a broader socio-economic module capturing local populace (in major ports), major fish markets, coastal development, catchment use and other marine industries. The framework fully integrates (i.e. all coupling is two-way) physical, ecological, economic and some social aspects of marine ecosystems, attempting to replicate all of the major steps in the management cycle using a management strategy evaluation approach. Links between different components are dynamic and spatially explicit (horizontal polygons, vertical layers) with time resolved down to 12 hours to capture both diurnal and seasonal shifts. The model is usually run out for a few decades to look at long term system dynamics. It is a highly complex deterministic model, which provides the user with suites of options as to the processes and formulations included in the model.
Model Dimensions and Model Structure	The model uses 71 polygons (boxes) with up to five vertical layers to represent 3.7 million km^2 of southeast Australia EEZ (including the Great Australian Bight, Tasmania and the eastern seaboard up to Fraser Island and out to the Lord Howe Rise). Temporal resolution is flexible (typically 12 hours). Hydrodynamic properties are derived from a fine scale hydrodynamic model. The model foodweb includes 64 ecological functional groups (species/groups) span from bacteria and plankton to macrophytes, fish, sharks, seabirds and marine mammals. 33 fleets (metiers) operate over 2 management jurisdictions (state and commonwealth), with 17 ports and 2

	major fish markets.
Usefulness of the Model (Pro, Cons, Problems)	Medium to long term strategic advice – uses a management strategy evaluation approach to consider the relative performance (vs objectives) of different options and any tradeoffs that may exist. Highly over parameterised versus available data so formal statistical fitting is infeasible. Parametric sensitivity analysis is rudimentary (focusing on the most sensitive and poorly known parameters) with multiple specifications used to cover uncertainty. Some structural uncertainty also included – primarily around potential food-web linkages. Cannot provide statistical robust short-term projections for ecosystems states and key species. Model pros: full integration across an entire marine system (natural and anthropogenic) with full two-way coupling. Modular (flexible) construction with all major ecological, fisheries and management processes available with multiple formulations in each case. Model structure is defined by the user, who also uses flags are used to configure the model accordingly. Model limitations: Highly complex and resource intensive – both in terms of time taken to develop and calibrate the model as well as run the final simulations- and typically highly data limited (making the end results uncertain). User interface is not particularly user friendly. The broad size of the polygons means it can not reflect very fine scale targeting by fishers.
Focus and Trade offs	The focus is at the system level, how the integrated system runs forward under alternative management options. Broad coverage means very fine scale dynamics are not always well captured (particularly fine scale fishing decisions, although a quasi-ABM option can mitigate this to some degree; model can also be coupled with other decision models, e.g. random utility model). Model size can be unwieldy when it is large and there is limited stochasticity.
Data needed	Initial conditions are required for all groups and fleets. All processes included in the model must be parameterised. This means there are high data demands across water column properties (temperature, salinity, oxygen), nutrients, size (at age) and abundance of each functional group or species. Initial effort and distributions, catch histories, vessel (include cost structure), gear and market characteristics. Details of all management rules in place and (of the quasi-ABM is used) the rough risk profiles and social network between fishers. If the other marine industries are being put in as background context then activity profiles or impact footprints are required (unless those industries are also fully dynamic in which case they will also need initial state and rate parameters). Forcing time series are needed for the physical properties, fuel prices and GDP.
Data available Used in case study/model	All the data outlined above was obtained, Data sourced widely from the Australian Fisheries Management Authority, industry, CSIRO, ABARES and academic institutions.
Status for application / implementation	Model is operational and used to provide management advice. A subset of this work has been published in the scientific literature, the majority is available through publically available technical reports. The modelling framework has now been implemented in more than 30 systems worldwide.
Model Platform and Programming Language (free, commercial)	Atlantis is a C++ program available from the CSIRO upon request (email Beth Fulton), under a royalty free licence and the terms and conditions set by CSIRO.
Model output	Model output is in NETCDF and ascii format. R code exists for

(format)	conversion into csv or other desired formats.

487 Baltic Sea Atlantis (Baltic ATL)

Case Study / Model	The Baltic Sea Atlantis (Baltic ATL)
Authors / Contact Persons*	Artur Palacz (arpa@aqua.dtu.dk), J. Rasmus Nielsen (rn@aqua.-dtu.dk), Asbjørn Christensen (asc@aqua.dtu.dk), Sieme Bossier (siebo@aqua.dtu.dk), Francois Bastardie (fba@aqua.dtu.dk), Henrik Gislason (hg@aqua.dtu.dk).
Aim: Management addressed, management objectives	Understanding the trade-offs in analyses and evaluation of fisheries management strategies such as spatial closures under scenarios of change in climate, eutrophication and fishing pressures. The model will address both the fish stock biological and broader socio-economic objectives behind strategic marine spatial planning and adaptive ecosystem-based fisheries management.
Aim: Corresponding advice needed/ addressed	The aim is to understand the broader cyclic feed-back between the ecosystem and the anthropogenic pressures in relation to marine spatial planning. The model output will provide long and medium term strategic advice concerning closed areas for fishing, windmill parks, large marine constructions, Natura 2000 areas, or evaluating ecological indicators relevant to EU MSFD (& DK WFD). Model results include estimates of net biological production of pelagic and benthic groups, and fisheries catch and revenue by fleet. The model results can be linked to e.g. physical-biological, bio-economic and socio-economic models (ERGOM, IBM DISPLACE, etc).
Institutional Set-up: (Bodies involved, needed partners);	Model developer: B. Fulton, CSIRO Mar. Res., Hobart, (AUS). Model implementation in the Baltic Sea: DTU-Aqua (University of Hamburg (D), Aarhus University (DK) and CSIRO) under the EU FP7 Vectors of Change project and the Danish Strategic Research Council IMAGE/MAFIA project together with data contributions from e.g., HELCOM, Baltic NEST institute, Stockholm Resilience Center, Finnish Game and Fisheries Research Institute.
Type of Model (ecol, econ, soc., long-term, short-term)	End-2-End Bio-Geo-Chemical Model with a hydrodynamic module, several pelagic and benthic ecosystem modules, fisheries management module and a broader socio-economic module. It covers the whole marine ecosystem, and it can fully integrate biological, social and economic aspects of the management cycle. Links between different components are dynamic and spatially (horizontal polygons, vertical layers) and seasonally explicit and are based on two-way coupling. It is a highly complex deterministic model. However, the user has the flexibility to choose among multiple modules of varying complexity including choice of different functional responses. The multi-species interactions are non-linear across all trophic levels resolved by age and stock structure. There is a detailed exploitation module which includes dynamics of fishing fleets, effort allocation and selectivity. Due to the modular construction management evaluation can involve different agents (e.g. also tourism, transport and energy).
Model Dimensions and Model Structure	The Baltic model resolves processes in three spatial dimensions based on 29 polygon-shaped boxes delineated across up to seven vertical layers. Temporal resolution is flexible (days to quarters). We define 33 biological functional groups (species/groups from bacteria and phytoplankton to fish, seabirds and marine mammals). There are separate but fully coupled biological and socio-economic procedures / modules..
Usefulness of the Model (Pro, Cons, Problems)	Medium to long term strategic management strategy evaluation to analyse trade-offs and in which direction the systems tend to move towards given different management options. Cannot provide statistical robust short-term projections for ecosystems states and key

	species. Model forces: flexibility of options for processes of predation, reproduction, growth, gape limitation, migration, invasive species, etc. as well as processes for monitoring, assessments, indicators, and fisheries economic analysis. Model limitations: Complexity and the large number of parameters complicate model informing (long build-up time hindered by cumbersome parameterization). Lack of balancing routines makes the process of model calibration long. Model simulations of scenarios potentially computationally demanding.
Focus and Trade offs	Useful framework to combine management input (i.e. what can we do) with a biophysical ecosystem model (i.e. what do we know) that captures key uncertainties. In a policy context, both the management input and the ecosystem model are then subject to the values of the public (i.e. what do we care about). On a strategic level the model is good for visualizing, for instance, trade-offs between harvest maximization and ecosystem structure.
Data needed	Being the most complex marine ecosystem model it requires much data ranging from physical and biogeochemical concentrations and fluxes, through life history parameters and population abundance and distribution, up to information on fishing fleet dynamics and economic value of ecosystem goods and services. Dimensions/Groups: See above, Type of Model and Dimensions. Hydrographical variables and parameters: Fields, fluxes, bio-geochemical processes, nutrient cycles (T, Sal, Oxygen, N, etc., etc.); Biological variables and parameters: Biomass, production (growth, reproduction, fecundity), diet (consumption, etc.), mortality (predation, fishery), migration, motility, habitat association, habitat dependency, etc. for different species and groups; Fisheries parameters: Effort, catch, revenue, etc. for different fleets and fisheries (metiers);
Data available Used in case study/model	No model results are yet available. As far as data used as model inputs are concerned, they are available from a number of sources.
Status for application / implementation	Atlantis has already been developed and applied in a number of marine ecosystems. The Baltic implementation is in an advanced stage. Currently, the model is being informed with data available from in situ and remote sensing monitoring, and where applicable, with results from previous or parallel modelling studies.
Model Platform and Programming Language (free, commercial)	Atlantis is written in C++ programming language. The model code is available from CSIRO Marine research upon request to Beth Fulton, under the terms and conditions set by CSIRO.
Model output (format)	Model output will be available in the standard large oceanographic data format of NetCDF. However, specific data requests will be processed to make results available in csv or xls format if needed.

494 California Current Atlantis Model (CA CURRENT ATL)

Case Study / Model	California Current Atlantis Model (CA CURRENT ATL)
Authors / Contact Persons*	Isaac C. Kaplan, Daniel S. Holland, and Elizabeth A. Fulton Contact : dan.holland@noaa.gov; isaac.kaplan@noaa.gov; Beth.Fulton@csiro.au
Aim: Management addressed, management objectives	The model was built to address the impacts of climate, oceanography, nutrient dynamics, and spatially explicit fishing effort on a dynamic food web. Specific evaluations for which applications of the model were developed include: understanding trade-offs between different uses and services of the ecosystem, evaluation of ITQ management vs. prior system; evaluating implications of shifting use of trawl gear to fixed gear and extending area closures for all gear with bottom contact; evaluating impacts of climate change and ocean acidification
Aim: Corresponding advice needed/ addressed	The model produces predictions of biomass and catch by species or functional group as well as estimates of revenue, profit and economic impacts including employment. While the model runs on a short time step and has the ability to provide short-term and near-term predictions its purpose is to provide medium and long-term advice of a strategic nature rather than tactical advice for specific management decisions such as setting TACs. Results are provided to the Pacific Fishery Management Council as well as other stakeholders in addition to being published. Model provides strategic advice on trade-offs in ecosystem uses and services which are included in the Integrated Ecosystem Assessment for the California Current (www.noaa.gov/iea/CCIEA-Report/index.html).
Institutional Set-up: (Bodies involved, needed partners);	Ongoing work is funded by NOAA and CSIRO. The Gordon and Betty Moore foundation provided funding for earlier model development on the US West Coast.
Type of Model (ecol, econ, soc., long-term, short-term)	Ecosystem model with bottom-up and top-down forcing, deterministic, spatial with irregular grid based on bathymetry and latitudinal breaks, dynamic with short time step.
Model Dimensions and Model Structure	The model extends from the US/Canada Border to Point Conception, California, and out to the 1200m isobath. The trophic dynamics represent 55 functional groups in the food web, using nitrogen as a common currency between groups. Functional groups are typically comprised of pools of 1 to 10 species with similar ecological roles. The model domain is divided into 62 spatial zones, each with up to seven depth layers. The model is forced with daily hydrodynamic flows, salinity, and temperature outputs from a high-resolution Regional Ocean Modeling System (ROMS, implemented by Hermann et al. (2009)).
Usefulness of the Model (Pro, Cons, Problems)	Atlantis model available now has a reasonably fine spatial scale capable of capturing heterogeneity of species distributions on the scale of 10-100km. However it is not finely enough resolved to capture true patchiness of species that fishermen may use to target stocks in the real world.
Focus and Trade offs	Focus is on linkages within ecosystem between physical and different biological and human components of system. A trade off is that specific species and fisheries cannot be modeled as realistically and uncertainty not addressed well since the model is not stochastic. The behavioral models for the fishing fleet are relatively simplistic.

Data needed	Model can be run with very simple fishing. Economic impacts can be calculated if Input Output model has been parameterized, For more detailed fleet dynamics, data on landings, logbooks, and cost-earnings are required. , in addition to ecological and oceanographic information. Could use better data on quota prices. Need better data on fine scale patchiness and short term spatial dynamics of fish stocks and fishing behavior which may be derived from analysis of observer data from the groundfish fishery.
Data available Used in case study/model	Data described above except quota price data were available and used.
Status for application / implementation	Model is operational for several applications and several have been published.
Model Platform and Programming Language (free, commercial)	Atlantis is written in C++ programming language. The code is retained by CSIRO (Australia) but shared broadly with collaborators.
Model output (format)	Results can be output in a variety of formats including csv and xls

Eco² Model: Basic Bio-Economic Module Describing the Dynamics of the Cohort Biomass related to Exploitation (ECO²).

Case Study / Model	Baltic cod fishereis/ Eco² model - Simple add on for the VPA
Authors / Contact Persons*	Dr. Eckhard Bethke, eckhard.bethke@thuenen.de
Aim: Management addressed, management objectives	The aim of the model is to give economic advice on intended management actions. These could be economic, technical or biological (biological, socio-economic objectives, harvest rules, technical measures, mesh opening).
Aim: Corresponding advice needed/ addressed	Bio-economic implications of alternative policies related. Basic module - allows single species models up to large ecosystem models.
Institutional Set-up: (Bodies involved, needed partners);	Developed by the Thünen Institute of Sea Fisheries
Type of Model (ecol, econ, soc., long-term, short-term)	Allows the development of single species models, but also the development of large ecosystem models.
Model Dimensions and Model Structure	From tiny to very large ecosystem models can be built up - it depends on the number of modules used in parallel.
Usefulness of the Model (Pro, Cons, Problems)	A special feature is the flexibility - it is not a model, but a basic building block for the construction of models in the strict sense.
Focus and Trade offs	Optimization of exploitation patterns
Data needed	Stock data, growth data, selectivity data, prices, discount rates
Data available Used in case study/model	ICES assessment data
Status for application / implementation	Model has been used to re-evaluate the current harvest control rule for Baltic Sea cod (paper submitted to Fisheries Research).
Model Platform and Programming Language (free, commercial)	Excel
Model output (format)	Excel

North Sea Ecopath with Ecosim and Ecospace (N SEA EwE)

Case Study / Model	North Sea Ecopath with Ecosim (EwE) and Ecospace (N SEA EwE)
Authors / Contact Persons*	Steve Mackinson (Cefas) steve.mackinson@cefas.co.uk; Focal point WGIMM Didier.Gascuel@agrocampus-ouest.fr
Aim: Management addressed, management objectives	Dynamic whole ecosystem model: Ecopath: Mass-balance of system, typology and food-web structure analysis, trophic flow analysis, Ecological Network Analysis, comparative ecology. Ecosim: Medium (<10 years) and long term strategic simulation of fisheries-ecosystem interactions and fisheries and environmental effect on food-web, evaluation (screening) of alternative management options. New model parameter uncertainty and management strategy evaluation routines suited to evaluation of ecological and fishery trade-offs and risk. New routine supported by R-codes for plotting results. Ecospace: Evaluation of spatial management strategies and changes in environmental conditions on the distribution of species and fishing activity. Short term simulation and forecast (1-3 years), introducing seasonality, dynamic/mechanisms at lower trophic levels/microbial loop not well represented. Even though representation of multiple life stages is possible, the majority of food web components are included as one compartment without age structure.
Aim: Corresponding advice needed/ addressed	Strategic medium to long term advice for combined multispecies and mixed fishery advice and fisheries effects on food web under different environmental conditions. Used in 2015 by STECF to evaluate options for a North Sea Multi-annual plan.
Institutional Set-up: (Bodies involved, needed partners);	Used mainly in academic context in the past, but the establishment of Key Runs (see ICES WGSAM reports) and management strategy evaluation tools intended for operational management advice, consistent with CFP and MSFD policy requirements. Led by Cefas, built on data from international data sources (mainly ICES and STECF) and specific species information for the North Sea.
Type of Model (ecol, econ, soc., long-term, short- term)	*Ecopath* (Polivina 1984, Christensen and Pauly 1992) is a mass-balance model quantifying interactions among predators and prey in marine food webs. Species or functional groups, ranging from plankton, to fish, and marine mammals. Landings and discard compositions of fishing fleets, together with detail of their economic performance, enables consideration of mixed fisheries issues simultaneously with multi-species issues. *Ecosim* (Walters et al. 1997) provides a dynamic simulation frame work to perform past analyses and forecast in order to evaluate the direct and indirect effects of fisheries and environmental change on ecosystem components, and to assess effects on the food web of various fishing scenarios or management options. *Ecospace* (Walters et al. 1999) extends Ecosim capabilities to account for spatial dynamics of species and fishing fleets. Using versioning control systems and a modular 'plug-in' approach, the software is under continuous development by several institutes around the world. Some recent developments include modules on parameter uncertainty analysis, Management Strategy Evaluation, Network analyses, Layer-based spatial modelling (Habitat capacity model) and tools for evaluation of MSY in a multi-species context.
Model Dimensions	– Multi fleet and multi species

and Model Structure	– Age disaggregation in species groups
Usefulness of the Model (Pro, Cons, Problems)	The model is best designed to address questions regarding processes that occur over the whole North Sea and on time scales greater than one year. As such the model is designed to help address strategic medium to long-term questions such as those relating to the long-term ecosystem effects of changes in fishing activity and climate. Multiple fleets are included based on DCF definition and Annual Economic Report data, enabling joint mixed fishery and multispecies effects. It is not useful for short-term (1-2 years) tactical questions regarding fisheries management, but can be used in complement with relevant tools to screen longer term impacts of tactical decisions as part of a risk analysis. It is complementary to existing approaches; helping managers and policy makers by giving them a view of the possible surprising and counter-intuitive effects of particular management and policy options. The structure of the model is also considered suitable to explore the effects of other disturbances, whether natural or anthropogenic. Evaluating spatial predictions, Romagnoni et al. (2015) concluded that the Ecospace model can predict quite successfully the species distribution, but not the distribution of fishing effort. The reason might be that Ecospace assumes spatial effort distribution to be driven mainly by profit, while other factors might be more important. The model might thus fail to capture fisher's behaviour accurately for this system. Work is presently underway to improve the spatial implementation given recent advances in the information available on fishing fleet distribution.
Focus and Trade offs	Ecopath: equilibrium ecosystem (mass balanced), where biomass accumulation is included the system is not in steady-state, but still adheres to mass-balance (Christensen and Walters, 2004). Ecosim: – Use of mass-balance results (from Ecopath) for parameter estimation – Forging arena theory (Walters and Martell 2004) as the foundation for representing predator prey interactions and its effect on the food-web dynamics. – Includes biomass dynamics for key ecosystem groups, using a mix of differential and difference equations. – Multi-stanza life stages for important components (a simplified ontogenetic structure) that includes structure by monthly cohorts, density- and risk-dependent growth – For multistanza groups, stock-recruitment relationships are an 'emergent' property of competition/predation interactions of juveniles. – Variable speed splitting for efficient modelling of the dynamics of both 'fast' (phytoplankton) and 'slow' groups (whales); Ecospace: – Habitat capacity model links species distributions with environmental conditions – Fleet distribution linked to sailing and distance weighted costs, but can be overwritten with data (e.g. inverse VMS effort)
Data needed	Ecopath – food web description data for each species/functional group: – Biomass (t/km^2) – Production/Biomass (y^{-1}) – Consumption/Biomass (y^{-1}) – Diet composition (%) – Catches, specified as landings and discards for each fleet

	– Fleet economics: landed values, including fixed and variable fishing costs – Biomass accumulation rates For multistanza groups – VBGF-k – Weight at maturity and W_∞ Ecosim - calibration data (those in bold are used to drive model dynamics, others used as data for fitting model predictions to during parameters estimation): – Fishing Mortalities (F) – Relative fishing effort for each fleet – Primary production anomalies (annual) – Biomasses absolute – Biomass relative (from stock assessments, surveys) – Catch – Mean weights – Total mortality (Z) Ecospace – data for specification of spatial distributions – 'Habitat' layers (e.g. depth, substrate) – Environmental condition layers (e.g. temperature, salinity) – Fishing costs – Dispersal rates – Advection and migration patters – Location of protected areas
Data available Used in case study/model	Data required were either available in ICES data base (yield, biomass and fishing mortality from stock assessment, IA from surveys,…), STECF or provided by partners around North sea. Detailed accounts of data sources are provided in relevant publications
Status for application / implementation	The North sea EwE model is used by the ICES working Group on Multispecies Assessment Methods (WGSAM), which developed regular key-runs (standardized model runs updated with recent data, producing agreed output and agreed upon by WGSAM participants) of the model. In its last meeting, in 2014, WGSAM examined a new plug-in routine (intended for release within the EwE software in 2015) developed for assessing the impact of model parameters uncertainty on the performance of alternative fishery management strategies. Through definition of harvest control rules and management regulations the routine allows users to examine consequences of discard policies consistent with an MSY framework. It is also relevant to evaluation of management strategies consistent with achieving GES (under MSFD) because harvest control rules (HCRs) for commercial species can be contingent upon conservation species. Future work will focus on publishing and application, ensuring robustness of the tool and routines for plotting results that are 'accessible' for managers and users.
Model Platform and Programming Language (free, commercial)	Open Source (www.ecopath.org) source code available on request with version control via SVN
Model output (format)	*Ecopath* – Mortalities (F; M2) consumptions, trophic flows, transfer efficiency, trophic levels (for group, for catch); food-web indices i.e. omnivore Index, ecosystem indicators. *Ecosim* –outputs per group or fleet - Biomasses; Mortality rates (F; M2), Consumptions; diet compositions, catches , electivity (standardised forge ratio), MSY, ecosystem indicators, fleet economic indicators (profit, costs).

Baltic Sea Ecopath with Ecosim Food-Web Model (B SEA EwE)

Case Study / Model	Baltic Sea, Ecopath with Ecosim food-web model (B SEA EwE)
Authors / Contact Persons*	Maciej T. Tomczak maciej.tomczak@su.se
Aim: Management addressed, management objectives	Evaluate the direct and indirect effects of fisheries and environmental change on ecosystem components.
Aim: Corresponding advice needed/ addressed	Strategic medium to long term advice for multispecies advice and fisheries effect on food web under different environmental conditions.
Institutional Set-up: (Bodies involved, needed partners);	Used in academic context; built on data from partners around Baltic sea
Type of Model (ecol, econ, soc., long-term, short-term)	Food-web dynamic simulations 22 functional groups Medium to long-term
Model Dimensions and Model Structure	Considers whole simplified food-web from primary producers (phytoplankton up to top predators (seals) 22 functional groups, 3 fishing fleets; at the moment the model covers ICES SD 25-29 exc GoF and GoR
Usefulness of the Model (Pro, Cons, Problems)	The model consists of functional groups (combine species) and an extensive number of input data are required. Short term simulation and forecast (1-3 years), introducing seasonality, dynamic/mechanisms at lower trophic levels/microbial loop not well represented. Even though representation of multiple life stages is possible, the majority of food web components are included as one compartment without age structure.
Focus and Trade offs	The model shows the effect fishing and environmental changes on food-webs, however so far focus on trophic flows, not at MSE and fisheries. Not stable enough SR relationship.
Data needed	Ecopath – food web description data for each species/functional group: ◎ Biomass (t/km2) ◎ Production/Biomass (y-1) ◎ Consumption/Biomass (y-1) ◎ Diet composition (%) ◎ Catches, specified as landings and discards for each fleet ◎ Fleet economics: landed values, including fixed and variable fishing costs ◎ Biomass accumulation rates For multistanza groups ◎ VBGF-k ◎ Weight at maturity and W∞ Ecosim - calibration data (those in bold are used to drive model dynamics, others used as data for fitting model predictions to during parameters estimation): ◎ Fishing Mortalities (F) ◎ Relative fishing effort for each fleet

	◎ Primary production anomalies (annual) ◎ Biomasses absolute ◎ Biomass relative (from stock assessments, surveys) ◎ Catch ◎ Mean weights ◎ Total mortality (Z)
Data available Used in case study/model	Ecopath – Mortalities (F; M2) consumptions, trophic flows, transfer efficiency, trophic levels (for group, for catch); food-web indices i.e. omnivore Index, ecosystem indicators. Ecosim –outputs per group or fleet - Biomasses; Mortality rates (F; M2), Consumptions; diet compositions, catches , electivity (standardised forge ratio), MSY, ecosystem indicators
Status for application / implementation	The model is currently in use for different studies on Baltic Sea, published (Tomczak et al. 2012, Tomczak et al. 2013)
Model Platform and Programming Language (free, commercial)	Open Source (www.ecopath.org) source code available on request with version control via SVN MS.NET, software package with GUI
Model output (Format)	raw txt data

546 Ecopath with Ecosim with Value chain module (PERU EwE)

Case Study / Model	Ecopath with Ecosim (EwE) value chain (PERU EwE). Case study published for the Peruvian fisheries sector, (Christensen et al., 2014), concluded for artisanal fisheries in NE Brazil (Bevilacqua et al., MS), and underway for Ria de Arousa Bay in NW Spain (Luis Outeiro and Sebastian Villasante, pers. comm.) – a bay with an aquaculture shellfish production of 250 kt/yr, employing more than 4500 people.
Authors / Contact Persons*	Villy Christensen (v.christensen@oceans.ubc.ca)
Aim: Management addressed, management objectives	A value chain module is included in EwE, linked to the static Ecopath, the dynamic Ecosim, and spatial-dynamic Ecospace modules as well as to the policy optimization and MSE modules (Christensen et al. 2011). The value chain module is designed to give a full description of the fisheries sector (from sea to plate) and is typically used coupled with EwE models that focus on the ecological and environmental aspects. The approach is mainly designed to evaluate trade off scenarios.
Aim: Corresponding advice needed/ addressed	Strategic medium to long term advice for multispecies advice and fisheries impact on the full fisheries sector, including under changing environmental conditions.
Institutional Setup: (Bodies involved, needed partners);	Designed and used to provide information to policy makers. Parameterization relies on close cooperation with the fisheries sector
Type of Model (biol, econ, soc., long-term, short-term)	Economic and social value chain module that is coupled with environmental-ecological food web model. Aimed for strategic evaluations (mid to long-term)
Model Dimensions and Model Structure	Flexible, relies on the underlying food web model
Usefulness of the Model (Pro, Cons, Problems)	Model considers demand-driven price elasticity, but predictions related to social and economic aspects otherwise do not consider major changes in, e.g., consumer preferences or market-driven changes that are external to the fisheries sector. The coupling of the environmental-ecological food web model and the socio-economic value chain opens for evaluating, e.g., impact of climate change on the entire fisheries sector, and notably allows more complete evaluation of tradeoffs related to fisheries management in a changing environment.
Focus and Trade offs	Focus is on the entire fisheries sector, from sea to plate. When coupled with dynamic EwE models this opens for evaluation of how environmental change may impact the fisheries sector from ecological, economic and social perspectives
Data needed	The value chain module can be parameterized with very detailed information about the revenue and cost structure by enterprise (producer, processor, distributor, wholesale, retail, …) or as an alternative, multiplicative factors can be used to describe increase in value and loss in biomass for each step in the value chain.
Data available Used in case study/model	The Peru case study relied on data collected by two researchers over a two-year period. The Brazilian case study was parameterized based on interviews collected by a PhD student over a one-year period. The Spanish case study is ongoing with data being collected by two researchers.
Status for application / implementa-	Method is implemented and freely available through the EwE modelling framework and software.

tion	
Model Platform and Programming Language (free, commercial)	Open Source (www.ecopath.org) source code available on request with version control via SVN. Model is programmed using (the freely available) Microsoft Visual Studio. Compiled software is available at www.ecopath.org.
Model output (format)	Results are available as table output, and include revenue and cost summaries as well as estimation of contribution to GDP. Result extraction is flexible and can be by species, by fleet, by enterprise or for the industry overall.

Ecopath with Ecosim and Ecospace (EwE General)

Case Study / Model	Ecopath with Ecosim (EwE) and Ecospace (EwE General).
Authors / Contact Persons*	
Aim: Management addressed, management objectives	Dynamic whole ecosystem model: *Ecopath*: Mass-balance of system, typology and food-web structure analysis, trophic flow analysis, Ecological Network Analysis, comparative ecology. *Ecosim*: Medium (<10 years) and long term strategic simulation of fisheries-ecosystem interactions and fisheries and climate effect on food-web, evaluation (screening) of alternative management options. *Ecospace*: Evaluation of spatial management strategies and changes in environmental conditions on the distribution of species and fishing activity. Short term simulation and forecast (1-3 years), introducing seasonality, dynamic/mechanisms at lower trophic levels/microbial loop not well represented. Even though representation of multiple life stages is possible, the majority of food web components are included as one compartment without age structure.
Aim: Corresponding advice needed/ addressed	
Institutional Setup: (Bodies involved, needed partners);	
Type of Model (ecol, econ, soc., long-term, short-term)	*Ecopath* is a mass-balance model quantifying interactions among predators and prey in marine food webs (Christensen and Walters 2004). Species or functional groups, ranging from plankton, to fish, and marine mammals. Landings and discard compositions of fishing fleets, together with detail of their economic performance, enables consideration of mixed fisheries issues simultaneously with multi-species issues. *Ecosim* (Walters et al. 1997) provides a dynamic simulation frame work to evaluate the direct and indirect effects of fisheries and environmental change on ecosystem components. *Ecospace* (Walters et al. 1999) extends Ecosim capabilities to account for spatial dynamics of species and fishing fleets. Using versioning control systems and a modular 'plug-in' approach, the software is under continuous development by several institutes around the world. Some recent developments include modules on parameter

	uncertainty analysis, Management Strategy Evaluation, Network analyses, Layer-based spatial modelling (Habitat capacity model) and tools for evaluation of MSY in a multi-species context.
Model Dimensions and Model Structure	– Multi fleet and multi species – Age disaggregation in species groups
Usefulness of the Model (Pro, Cons, Problems)	
Focus and Trade offs	Ecopath: equilibrium ecosystem (mass balanced), where biomass accumulation is included the system is not in steady-state, but still adheres to mass-balance. Ecosim: – Use of mass-balance results (from Ecopath) for parameter estimation – Forging arena theory (Walters and Martell 2004) as the foundation for representing predator prey interactions and its effect on the food-web dynamics. – Includes biomass dynamics for key ecosystem groups, using a mix of differential and difference equations. – Multi-stanza life stages for important components (a simplified ontogenetic structure) that includes structure by monthly cohorts, density- and risk-dependent growth – For multistanza groups, stock-recruitment relationships are an 'emergent' property of competition/predation interactions of juveniles. – Variable speed splitting for efficient modelling of the dynamics of both 'fast' (phytoplankton) and 'slow' groups (whales); Ecospace: – Habitat capacity model links species distributions with environmental conditions – Fleet distribution linked to sailing and distance weighted costs, but can be overwritten with data (e.g. inverse VMS effort)
Data needed	Ecopath – food web description data for each species/functional group: – Biomass (t/km^2) – Production/Biomass (y^{-1}) – Consumption/Biomass (y^{-1}) – Diet composition (%) – Catches, specified as landings and discards for each fleet – Fleet economics: landed values, including fixed and variable fishing costs – Biomass accumulation rates For multistanza groups – VBGF-k – Weight at maturity and W_∞ Ecosim - calibration data (those in bold are used to drive model dynamics, others used as data for fitting model predictions to during parameters estimation): – Fishing Mortalities (F) – Relative fishing effort for each fleet – Primary production anomalies (annual) – Biomasses absolute – Biomass relative (from stock assessments, surveys) – Catch – Mean weights

	– Total mortality (Z) Ecospace – data for specification of spatial distributions – 'Habitat' layers (e.g. depth, substrate) – Environmental condition layers (e.g. temperature, salinity) – Fishing costs – Dispersal rates – Advection and migration patters – Location of protected areas
Data available Used in case study/model	
Status for application / implementation	Some live examples include: North Sea, central Baltic Sea, Channel, West coast of Scotland, Celtic sea, Scotian shelf, Gulf of Maine, Georges bank. *More examples are given in WGSAM 2007 review on modelling in ICES ecoregions*
Model Platform and Programming Language (free, commercial)	Open Source (www.ecopath.org) source code available on request with version control via SVN
Model output (format)	*Ecopath* – Mortalities (F; M2) consumptions, trophic flows, transfer efficiency, trophic levels (for group, for catch); food-web indices i.e. omnivore Index, ecosystem indicators. *Ecosim* –outputs per group or fleet - Biomasses; Mortality rates (F; M2), Consumptions; diet compositions, catches , electivity (standardised forge ratio), MSY, ecosystem indicators, fleet economic indicators (profit, costs).

Generic Ecosystem Model (GEM)

Case Study / Model	Generic Ecosystem Model (GEM)
Authors / Contact Persons*	Lars Ravn-Jonsen, lrj@sam.sdu.dk Ken Haste Andersen, kha@aqua.dtu.dk
Aim: Management addressed, management objectives	• Bioeconomic model regarding total harvest of the ecosystem. • Strategic planning model: Strategic goal for harvest with respect to size of fish (trophic level) and mass • Capital theoretic analyses by marginal approach • Analyze of diving forces for ecosystem degradation based on the capital theory • Benefit indicator to inform about trade offs between e.g. forage fish fishery and large fish fishery • Benefit indicator to inform about inter temporal trade offs
Aim: Corresponding advice needed/ addressed	• The model can find the first best strategic goal with respect to size and amount of ecosystem harvest. • The model can find the return rate given by ecosystem by investment made by increasing size or decreasing harvest by marginal analyses. • The marginal analyses point to problems to be addressed by regulations of common pool regulation. • The model illustrates how one fishery through the ecosystem affects other fisheries
Institutional Setup: (Bodies involved, needed partners);	Used by: Lars Ravn-Jonsen, SDU Documented in Ravn-Jonsen (2011); Andersen et al. 2014; Ravn-Jonsen et al. 2016 Similarly models used by DTU aqua and Cefas Needed partners: Biologists / Ecologists working with Ecosystem management with a strategic approach.
Type of Model (biol, econ, soc., long-term, short-term)	Type of model: Bioeconomic model with the biological model as a trophic dynamic model with size as functional group, thus a size based mode, and the economic model that allows for flexible fishery with respect to size and functional groups. The model implementation allows for capital theoretic analyses by a marginal approach, or use of a benefit indicator based on cost effectiveness principles Level and complexity: Ecosystem level modeled by functional groups, long term with time scale of 50-years, no spatial resolution. Economic model target welfare economic and optimizing of capital value at ecosystem level, and regulation at functional group level (size) and sizes disgusted by asymptotic size
Model Dimension and Model Structure	State variable is population density with respect to size and asymptotic size. Size, asymptotic size and time is modeled continues and the numeric implementation allows for any resolution with respect to size, asymptotic size and time step. Fishery is implemented so any selectivity or fleet structure can be applied. There is full integration of economics, but no agent based adaptation. In Ravn-Jonsen (2011) there is only one fleet and that fleet is targeting one size.
Usefulness of the Model (Pro, Cons, Problems)	Pros: Quick and simple, suitable for capital theoretic analysis. The biological model is a production model (in the economic sense) with dynamic based explicit linking mortality consumption and somatic growth based on physiological and ecological principles Cons; the simplicity will miss aspects, however they can be ad-

	dressed by other models
Focus and Trade offs	Focus: Strategic planning
Data needed	Parameterize the model for specific systems.
Data available Used in case study/model	Generic physiologic functions. Size spectrum analyses
Status for application / implementation	Status: published, Ravn-Jonsen (2011); Andersen et al. 2014; Ravn-Jonsen et al. 2016
Model Platform and Programming language (free, commercial)	MATLAB, R (free)
Model Output (Format)	Population density, harvest, rent, indicator rate, benefit indicator.

Integrated model for Australian Torres Strait Tropical Rock Lobster (IMATSTRL)

Case Study / Model	Integrated model for Australian Torres Strait Tropical Rock Lobster (IMATSTRL)
Authors / Contact Persons*	Plaganyi, Eva (Eva.Plaganyi-Lloyd@csiro.au) Deng, Roy (Roy.Deng@csiro.au) Dennis, Darren (Darren.Dennis@csiro.au) Hutton, Trevor (Trevor.Hutton@csiro.au) Pascoe, Sean (Sean.Pascoe@csiro.au) van Putten, Ingrid (Ingrid.vanputten@csiro.au) Skewes, Tim (Tim.Skewes@internode.on.net)
Aim: Management addressed, management objectives	The model was developed as part of a Management Strategy Evaluation (MSE) to support the management of the Torres Straits Rock Lobster (TRL) fishery. The MSE was to inform the policy initiative that was in place to transition the fishery from access and input controls to controlling the amount of catch (output control – via quota management). The needs of traditional and commercial users under the Torres Strait Treaty between Australia and Papua New Guinea also needed to be balanced. The model was key in gaining an understanding and comparison of indigenous fishers' perceptions of the potential impact of different Quota Management System (QMS) approaches. The model captures environmental (biological), market- based economic, and social objectives in a fishery characterized by a substantial traditional and cultural component as well as a commercially oriented sector.
Aim: Corresponding advice needed/ addressed	The aim was to develop a fully integrated MSE that takes into consideration biological, economic, cultural and social aspects of the fishery. A spatial-aggregated single species bio-economic model was used to predict quota reallocation under different quota management approaches .The assumption that technical efficiency and capacity utilisation were suitable predictors of which boats are likely to exit the fishery was tested and scale efficiency was considered as an alternative predictor. Due to the importance of the indigenous fleet the bio-economic model also considered social drivers. The variability in participation of indigenous fishers under key economic and socio-cultural drivers, such as the availability of a government employment program, lobster prices, social capital and capacity, and infrastructure availability was modelled using a Bayesian Network (BN) approach. The probabilities of Indigenous fisher participation and effort were able to be established under different socio-economic conditions. Using the BN approach the increase or decrease in two dynamic continuous social indices, linked to the biological and economic model, could be measured.
Institutional Set-up: (Bodies involved, needed partners);	*Commonwealth Scientific and Industrial Research Organisation* (*CSIRO*): Model development, data gathering, and data analysis Torres Strait Regional Authority: collaboration, Indigenous knowledge and local contacts for consultation purposes Australian Fisheries Management Authority: logbook data for commercial fisheries and voluntary data for indigenous fishery used for model conditioning Processors and commercial operators: Provided data Local indigenous community: provision of voluntary log book data and involvement in consultation process

Type of Model (biol, econ, soc., long-term, short-term)	A spatial-aggregated single species bio-economic model conditioned using all available data (biological, social, and economic) and describing the lobster and fishery dynamics in each of 16 linked areas. The model can be used to assess the implications of different share allocations between the traditional and commercial sectors, on the individual fleet profits, value added and employment per sector.
Model Dimensions and Model Structure	The **Biological model** is an age-structured, discrete-time model with recruitment, natural mortality and fishing mortality parameters and provides number and weight of lobsters by area, year, month and age. The original spatial dis-aggregated age-structured model (more formally, it is a Statistical Catch-at-Age Analysis) has a monthly time step and is simultaneously applied to the Torres Straits and Queensland East Coast regions. The spatial operating model is conditioned using all available data (biological, social, and economic) and describes the lobster and fishery dynamics in 16 linked areas. The bio-economic model applies a spatially-aggregated version of the model. The **Economic model** separately includes the main fleets and explicitly takes into account their unique cost structures. The bio-economic model (1) computes profit per sector; (2) includes the flow-on effects (value added) through inclusion of the supply chain; and (3) includes exogenous effort multipliers based on a Bayesian Network (BN) model of the same fishery In total, the economic analysis includes a production function and frontier analysis, and a data envelopment analysis [to estimate which non-indigenous vessels might exit the fishery with lower quota levels]. Estimates of owner-operator returns to labour for the indigenous operators and the flow-on effects, by including aspects of the supply chain, are evaluated. The **Social/cultural model** is based on a semi-quantitative Bayesian Network analysis. The BN was used to examine the variability in participation of subgroup of indigenous fishers (which were based on a typology of activity) under key economic and socio-cultural drivers. Through estimation of fisher participation in each of the three indigenous subfleets using the BN, the model allows for dynamic feedback between social indices and the system dynamics. Participation is the key driver of effort, and changes in effort and stock biomass impact on projected catch per year.
Usefulness of the Model (Pro, Cons, Problems)	Because the tropical rock lobster is a relatively short-lived recruit-driven species and the catch is capped each year, in this particular fishery there was no imperative to estimate long-term future participation beyond the timeframe of the biological cycle. That is, long-term investment decisions could be linked to profit per sector explicitly. However, long-term feedback could be modelled should this approach be implemented for a fishery with a longer-lived species.
Focus and Trade offs	The model provides estimates of biomass and fishing mortality. The economic and social components provide estimates of sub-fleet profitability, supply chain added values and indigenous fisher participation. The MSE approach makes explicit the trade-offs between environmental, economic and social objectives.
Data needed	Most of the uncertainty in the biological component of the model is the natural mortality of the stock, and the steepness parameter of the stock-recruitment functions. The uncertainties in the social and economic models are mainly related to estimated indigenous fisher participation and fishing effort. In addition the cost of fishing for the indigenous fleet may be

	more variable than assumed in the model. Value added in the supply chain is highly dependent on type of product (live lobster versus tails) and price which also has inherent uncertainties.
Data available Used in case study/model	Commercial fleet logbook data and voluntary logbook data is held by the Australian Fisheries Management Authority (AFMA). The data resulting from the biological model is available to the fisheries management committee (a Resource Assessment Group) for decision making purposes.
Status for application / implementation	The model was used to undertake a full MSE for this fishery. The biological component is used in stock assessment for the fishery and a 'recommended' TAC is provided. As output controls have not officially been instated in this fishery the TAC is as yet not binding.
Model Platform and Programming Language (free, commercial)	Netica for the Bayesian Network analysis R- for the economic analysis The model is implemented in AD Model Builder (Fournier et al. 2011) which uses automatic differentiation, and is suitable for highly nonlinear models with a large number of parameters.
Model output (format)	Excel compatible format

Size-spectrum bioclimate envelope model & Input/Output tables (SS-DBEM-IOT)

Case Study / Model	Size-spectrum bioclimate envelope model & Input/Output tables (SS-DBEM-IOT)
Authors / Contact Persons*	Jose Fernandes jfs@pml.ac.uk
Aim: Management addressed, management objectives	Medium and long term scenarios of species exploitation in relation to species MSY (and multipliers) considering climate and environmental change. Further economic and social impacts on the fisheries and associated industries.
Aim: Corresponding advice needed/ addressed	Test what-if scenarios and integration of new biological and economic knowledge. Changes in biomass, abundance, potential catches and size-structure. Changes in socio-economic indicators such us employment and revenue.
Institutional Set-up: (Bodies involved, needed partners);	Plymouth Marine Laboratory (PML), University of British Columbia (UBC) and CEFAS. Not always all of them needed.
Type of Model (biol, econ, soc., long-term, short-term)	Bioeconomic model based on scenarios projection; medium and long-term. Multispecies. Multiple economic and social indicators. Considers size-spectrum theory, habitat suitability, ecophysiology, population dynamics, larvae and adult dispersal.
Model Dimensions and Model Structure	It allows interactions between species using habitat suitability and size-spectrum theory. Multiple species at multiple sizes. Usually runs from 1950 to 2100. Resolution 0.5 x 0.5 degrees.
Usefulness of the Model (Pro, Cons, Problems)	Pros: Flexibility to add species and work on areas with poor data. Flexible to adapt to new needs. Integration with theoretical and empirical and experimental work. Cons: Long time to run that scales with the number of species to be considered.
Focus and Trade offs	Depends on scenarios definition.
Data needed	For each target species of the fishery: growth parameters; length-weight parameters; population intrinsic rate parameter; metabolic rate; adult and juvenile natural mortality and dispersal rates; initial distribution and fishing mortality For each fleet in the fishery: number of boats; general costs of the fleet and specific costs of individual vessels (or average per vessel in a fleet) For each species: average price per species; Economic sector specific statistics.
Data available Used in case study/model	The model is parameterised from biological and economic data obtained from specific research projects and public databases such as SeaAroundUs and ICES.
Status for application / implementation	Model is operational, but adapted for each specific project. This includes recent adaptations to consider ocean acidification.
Model Platform and Programming Language (free, commercial)	.net; Fortran, language R
Model output (format)	Csv files