Challenges in Implementing Stock Assessment, Economic Fishery Analysis, and Risk Assessment for Sustainable Management Strategies of Data Poor Stocks

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Abstract
Under the IIFET[*1] 2018 Special Session "Tools for Stock Assessment, Economic Fishery Analysis, and Risk Assessment for Sustainable Management Strategies of Data Poor Stocks in Mixed, Small Scale and Indigenous Fisheries" a number of stakeholder presentations addressed the current status, challenges, needs and future perspectives for implementation of management and ecological / economic assessment of data poor fish stocks and fisheries in management advice. This covers methods, simulation models and management strategy evaluation (MSE) tools to conduct assessment and evaluate economic efficiency and risks in exploiting data poor stocks caught in mixed, small scale, and indigenous fisheries. Particular focus is on accessibility of models and their development to ensure widespread and open access availability, user-friendly model operation, and efficient widespread adoption and implementation of those by scientists, stakeholders, and managers. Additional focus is on the data requirements for those models. Finally, the aim of the session was to discuss the best possible way to link economic assessments, risk assessment and MSE with biological (ecological) assessment of stock status according to sustainable harvest levels in those data limited situations and systems to provide robust assessment and advice – and maybe even integrated ecological-economic advice?

Introduction
In ICES[*2] there is an ongoing extensive advisory and scientific strategic initiative with respect to development and implementation of assessment methods for data limited and data poor stocks that involves integrating the stocks into TAC (Total Allowable Catch) advice according to the MSY (Maximum Sustainable Yield) and PA (Precautionary Approach) principles.

Such a focus is important because most fish and shellfish stocks in the world are in a data poor or a data limited condition/situation, and those stocks are to a much higher extent over-exploited and poorly managed than data rich stocks which most often are well managed. This is especially needed and urgent in a mixed, small scale and indigenous fisheries management context, in order to achieve the objectives of an ecosystem-based approach to fisheries management set out in UNCLOS[*3] and its follow up in the Johannesburg 2002 Declaration.

Among others ICES[*2], PICES[*4], NAFO[*5], and FAO[*6] have major focus on this situation and try to improve the advisory methods and provide necessary knowledge and expertise to meet this situation. Under the ICES there have recently been reviewed and evaluated a large number of methods and models to enable assessment of data limited and data poor stocks and associated fisheries dynamics, management strategy evaluation (MSE), and fisheries advice. It has also involved development of advanced stochastic stock assessment models to provide MSY and PA advice. Here focus is especially on stocks acting as choke species in mixed fisheries as well as stocks in small scale and indigenous fisheries. Also methods and models using time series of fishery research survey and/or fishery information, either independently or on integrated basis, have been developed to assess fish and fishery resource abundances and variability herein on an area specific and seasonal basis which can also be used for data limited stocks.

Further needed economic progress and evaluation: There is a growing need for economic methods, simulation models and MSE tools to be developed and implemented on top of the biological evaluation enabling economic assessment and establishment of indicators of economic sustainability of fisheries that exploit data poor and data limited stocks. This involves development and implementation of robust methods to evaluate efficiency, risks, sensitivity and robustness of different management strategies for mixed, small scale and indigenous fisheries where data poor and data limited stocks are caught, either as intended or un-intended by-catch or as target species. The medium to long-term economic profitability is part of incentive for improving fisheries management, economic efficiency and ecological sustainability in the exploitation and management of those stocks. To enable sustainable development of data poor stocks this should be the targeted goal. To achieve this, the management needs to consider economic efficiency in the fishery accounting for fishermen behavior and overall incentives for exploitation.

Consequently, it is urgently necessary and important to review, investigate and discuss appropriate economic principles, methods, simulation models and MSE tools to evaluate economic viability and conduct risk assessment and robustness checks of different management strategies and harvest control rules for those stocks and fisheries. Also it is relevant to identify, review and evaluate performance of those methods and their data needs according to their ability to provide efficient economic input to tactical and strategic management advice in data poor or limited stock situations. This is an important step toward achieving sustainable management and avoiding choke-species issues in high-value mixed fisheries as well as to ensure sustainability of small scale and indigenous fisheries.

Aim: In context of the above, the aim of the present session and paper was to present state-of-the-art developments within a set of new methods, simulation models and MSE tools and on this basis to obtain stakeholder feed-back on the developments and future perspectives and needs. This was achieved by presentations and feed-back commenting from invited stakeholder representatives from fishing industry, fisheries management, fisheries advice (ICES), and fisheries biological and economic science who presented their perspectives and views on the above challenges.

The present paper gives summaries of the set of new methods and tools initially presented at the session as well as summaries of the follow-up and feedback presentations and discussions provided by the stakeholders. On this basis, the paper draw some general conclusions on developments, challenges and future needs in relation to data poor stock assessment and management strategy evaluation in an ecological and economic perspective.

Summaries of Presentations of Some Recent Method and Tool Developments

1. Advancing assessment methods for data-limited fish stocks

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The assessment of data-limited fish stocks is crucial for the sustainable management of marine living resources. Dependent on the scope and type of available data, a range of assessment methods are available, such as catch only, length-based, or catch and survey-based methods. However, these methods suffer from several shortcomings, such as assuming equilibrium, over-simplifying biological processes and ecological interactions, and lacking quantification of assessment uncertainty. Here, we present several advancements of data-limited stock assessment methods tackling some of these limitations. The s6model (Kokkalis *et al.*, 2015; 2017) and updated traditional length-based assessment methods allow deriving biological reference levels from one year of length-frequency data while quantifying the assessment uncertainty. The stochastic production model in continuous time (SPiCT; Pedersen and Berg, 2017) requiring only catch and CPUE time series quantifies differences between seasonal patterns in the fishing mortality and productivity. The stage-based biomass dynamic model building upon SPiCT resolves biomass dynamics between the juvenile and adult stages, which improves the predictability of future biomass levels. The incorporation of stochastic data-limited methods into management strategy evaluation frameworks reveal appropriate harvest control rules for different stocks and how to account for the assessment uncertainty. The implementation and further development of such methods will contribute to a biological sustainable management of marine living resources, and provide robust platforms for additional quantitative economic analyses of the fisheries exploiting the resources.

Overcoming limitations of length-based methods

Length-based methods represent an important class of models for the assessment of data-poor and data-limited fisheries. Length measurements are relatively easy and cost-effective to collect and can be used to estimate life-history traits of the species and sustainability reference levels, such as SPR, F_{MSY}, or $F_{0.1}$ (e.g. Herrón *et al.*, 2018). However additionally to fishing effort, three other processes shape and influence length-frequency distributions: gear selectivity, recruitment variability, and non-representative sampling. This underlines the importance to quantify the uncertainty of underlying data and/or estimated parameters. The s6model accomplishes that by sampling from a distribution of suitable input parameters (Kokkalis *et al.*, 2015; 2017), however for many traditionally used length-based assessment methods, this has not been possible so far. Therefore, the length-based assessment routine, consisting of ELEFAN, length-converted catch curve analysis, and the yield per recruit model (Mildenberger *et al.*, 2017; Taylor and Mildenberger, 2017), was wrapped within a bootstrap approach (Schwamborn *et al.*, 2018; Mildenberger *et al.* (accepted)). By resampling the data and re-estimation of all parameters, they are estimated with non-parametric distributions (Fig. 1). The new method provides confidence intervals in addition to point estimates. This allows not only to adjust the management advice (e.g. recommended TAC) by the amount of uncertainty, but can also identify cases where available data is not sufficient for the assessment with length-based methods and can then inform which additional data would be needed to improve the assessment.

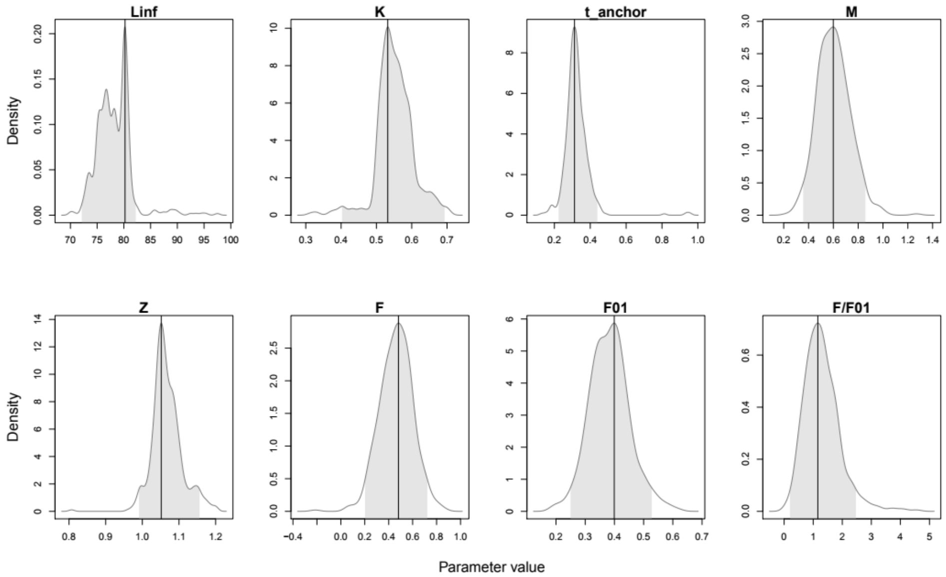

Figure 1: Parameter distributions estimated with the bootstrapped length-based fish stock assessment approach. The vertical lines represent the maximum density estimate and grey shaded area represent the 95% confidence intervals.

Advancing surplus production models

Surplus production models are another valuable class of methods for the assessment of data-limited fisheries, as they only require a time series of catches and of effort or a survey biomass index. A common criticism against these methods is that they assume a constant carrying capacity and productivity over the whole period of available time series, while empirical evidence and simulations point at the importance of time-variant parameters (Vert-pre *et al.*, 2014; Britten *et al.*, 2017). A set of five model extensions of SPiCT allows to model time-variant productivity within SPiCT as long-term step-wise shifts between productivity regimes or long-term gradual changes, as well as seasonal oscillating productivity (Mildenberger *et al.*, submitted). Simulation testing revealed that estimated reference levels and stock status is biased when seasonal productivity is not accounted for and that the relative biases and uncertainties depend on the characteristics of the seasonal patterns (fishing mortality and productivity), such as the relative amplitudes and positioning of the peaks, as well as the number of survey indices per year (Fig. 2a,b). The application of the time-variant SPiCT to Eastern Baltic cod showed that the model can resolve seasonal fishing mortality and productivity and long-term changes in productivity (Fig. 2c,d), and that estimated variability in the productivity correlates well with environmental conditions and ecological processes (Mildenberger *et al.*, submitted). Production models such as SPiCT oversimplify population dynamics by regarding the population as an unstructured biomass pool. We are thus exploring feasibility of a stage-based implementation of SPiCT, which allows to model the dynamics of the juveniles and adults separately, thus reflecting the population structure more realistically, without having higher data requirements.

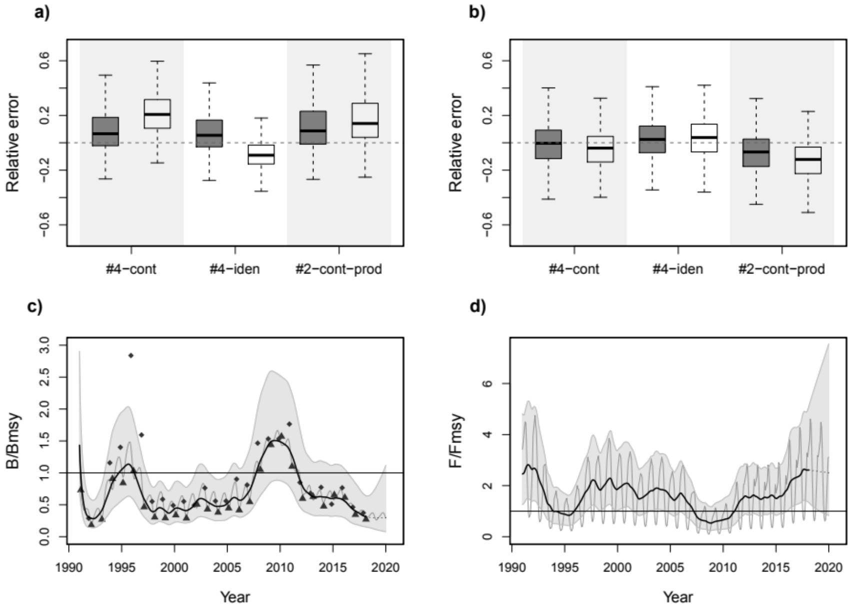

Figure 2: Relative error of SPiCT in estimated values of B/Bmsy (a) and F/Fmsy (b) when accounting for seasonal oscillating productivity (dark grey boxplots) and neglecting it (light grey boxplots). The errors are shown for 3 different scenarios: Simulations with 4 indices per year and a contrasting pattern of the seasonal fishing and productivity processes, 4 indices per year and an identical pattern of those processes, and 2 indices with a contrasting pattern but a stronger relative productivity process. 2C and d show the estimated time-variant trends in productivity for the Eastern Baltic cod for B/Bmsy and F/Fmsy, respectively. The black trajectories represent the relative states of the stock in each year with estimated 95% uncertainty intervals as grey shaded area. The light grey trajectories represent the seasonal patterns and the symbols in 2c show the observations from the biomass surveys.

2. Applying the decision support tool FishPath to guide the establishment of a fisheries management system in Indonesia

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When data are insufficient to assess fish stocks using conventional techniques, there are a growing number of options for collecting data, estimating stock status, and translating measures of stock status into management action. The FishPath application is a user-friendly web-based decision support tool that brings together a broad collection of these techniques. Using FishPath, the concepts of data collection/monitoring, stock assessment and management control rules can be considered collectively to draft complete harvest/management strategies. It was specifically created to demonstrate which of a variety of options may be possible for monitoring, applying stock assessments and identifying control rules for data-limited fisheries. Each section has roughly 40-50 questions and provides detailed analytics for exploring assumptions in the many available options. It also underscores where uncertainty should be explored and how future improvements can lead to adaptive management. We demonstrate this tool as applied to data-limited fisheries in Indonesia. Both tactical and strategic decisions are made more transparent and tenable, while the vast possibilities to manage a fishery are made explicit and achievable. The tool is applicable to any fishery, and can provide guidance and hope when confronting the vast challenge of establishing management systems in resource limited fisheries.

What to do when data are limited?

Example Data Collection Question

- Are fishers, or can fishers be, incentivized/ motivated to be involved in a data collection program?
  - Yes
  - No

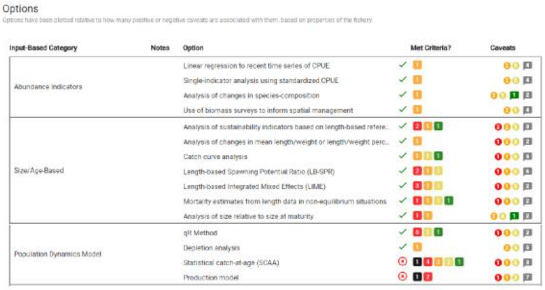
Example Assessment Question

- Categorize the nature of the fishery in terms of its main market or activity. If the market or activity is mixed, select the highest market level
  - Small-scale recreational
  - Subsistence
  - Subsistence-artisanal
  - Large-scale sport fishing
  - Artisanal-commercial
  - Commercial-industrial

Example Management Questions

- Is the fishery multispecies, either in terms of target or bycatch species?
  - Yes
  - No
- Is it possible to calculate, or define a proxy for, a target or limit reference point?
  - Yes
  - No

Example Assessment Results: Can and Can't

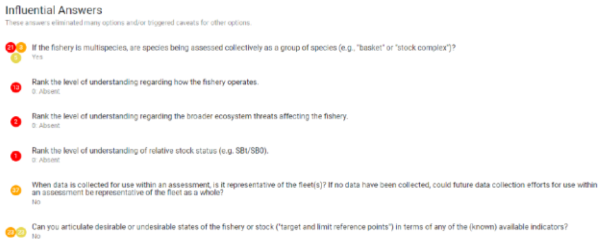


Options

Options have been plotted relative to how many positive or negative caveats are associated with them, based on properties of the fishery.

Input-Based Category	Notes	Option	Met Criteria?	Caveats
Abundance indicators		Linear regression to recent time series of CPUE	✓	
		Single-indicator analysis using standardized CPUE	✓	
		Analysis of changes in species-composition	✓	
		Use of biomass surveys to inform spatial management	✓	
Size/Age-Based		Analysis of sustainability indicators based on length-based refere...	✓	
		Analysis of changes in mean length/weight or length/weight perc...	✓	
		Catch curve analysis	✓	
		Length-based Spawning Potential Ratio (LB-SPR)	✓	
		Length-based Integrated Mixed Effects (LIME)	✓	
		Mortality estimates from length data in non-equilibrium situations	✓	
		Analysis of size relative to size at maturity	✓	
Population Dynamics Model		qR Method	✓	
		Depletion analysis	✓	
		Statistical catch-at-age (SCAA)	⊗	
		Production model	⊗	

Influential Answers: Future Options



Influential Answers

These answers eliminated many options and/or triggered caveats for other options.

If the fishery is multispecies, are species being assessed collectively as a group of species (e.g., "basket" or "stock complex")?
Yes

Rank the level of understanding regarding how the fishery operates.
0: Absent

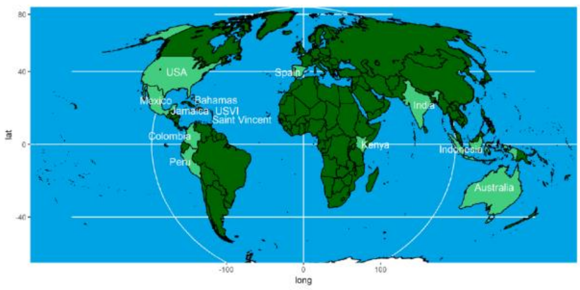
Rank the level of understanding regarding the broader ecosystem threats affecting the fishery.
0: Absent

Rank the level of understanding of relative stock status (e.g. SBt/SB0).
0: Absent

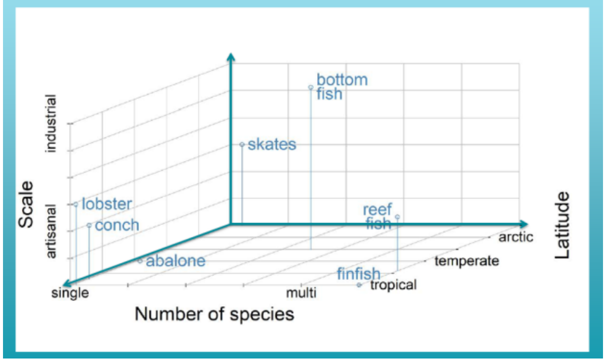
When data is collected for use within an assessment, is it representative of the fleet(s)? If no data have been collected, could future data collection efforts for use within an assessment be representative of the fleet as a whole?
No

Can you articulate desirable or undesirable states of the fishery or stock ("target and limit reference points") in terms of any of the (known) available indicators?
No

FishPath Use: Over a dozen countries on 6 continents



FishPath Use: Artisanal, Tropical, and Multispecies



In summary of our studies and the Take-Home Messages:

- Conventional stock assessment models work well, but only when extensive data are available. Most of the time, we lack these data.
- Even when data are quite limited, FishPath can guide us towards a feasible system of data collection, assessment, and management options.
- FishPath aims to provide status estimates and management advice for nearly any fishery.
- We can assess and manage the vast majority of fish stocks, across a wide range of fisheries.
- Our assessment toolbox is extensive and, with FishPath, more accessible than ever.

3. Alternative Harvest Control Rules For Multi-Fleet and Multi-Species Tuna Fisheries under Data-Poor Conditions in Eastern Indonesia

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Indonesian tuna fisheries are complex due to variation in the scale and size of fleet in the fisheries, the highly dispersed distribution, and their multi-species nature. Moreover, there are large problems with data collection. Like many developing-country fisheries, their management needs to consider many other goals besides rents maximization, such as the distribution of rents and the stability of income and employment. This study evaluates the performance of alternative harvest control rules by means of a stochastic bio-economic model integrating the characteristics of three different scales of fishing and two tuna species. We focus on skipjack (*Katsuwonus pelamis*) and yellowfin tuna (*Thunnus albacares*) fisheries in the eastern Indonesia in small-scale (SSF), medium-scale (MSF), and large-scale fisheries (LSF). We combine the dynamics of an age-structured production model and the economic performance of fishing activity. In this study, simulation of management strategy evaluation (MSE) consists of 5 years simulation for operating model and continue with 25 years of projection alternative harvest control rules (HCRs). We use monitoring data of effort and catch per unit effort (CPUE) to decide the allocation of effort in numbers of vessels in the next year.

This study simulates three scenarios of HCRs: 1) Effort is a function of last year's effort (Effort-based); 2) Effort is a function of CPUE (CPUE-based); and 3) Effort is a function of CPUE with a minimum effort available to small-scale fisheries (SSF protection-based). In scenario HCR1, we simulate three alternatives: a constant effort (HCR1a), a significant increasing of effort for 50% in the first year of projection year and continued with constant effort (HCR1b), and a constant increasing effort with about 1% per year (HCR1c). In scenario HCR2, the number of vessels for next year is depending on the changes in CPUE. We apply two HCRs in the scenario: without restriction on the changes of effort (HCR2a) and with restriction on the changes of effort by maximum of 20% (HCR2b). We combine HCR2 with an additional restriction on the minimum number of vessels for SSF vessels for HCR3a (without restriction on the changes of effort) and HCR3b (changes of effort by maximum of 20%). To account for the multi-species nature of the fisheries, we apply a precautionary approach in the decision making in HCR2 and HCR3 by taking the lowest suggested effort for next year's allocation. We test 50 sequences of slopes and chose a slope with the highest fishing rent at the end of projection year (Figure 1).

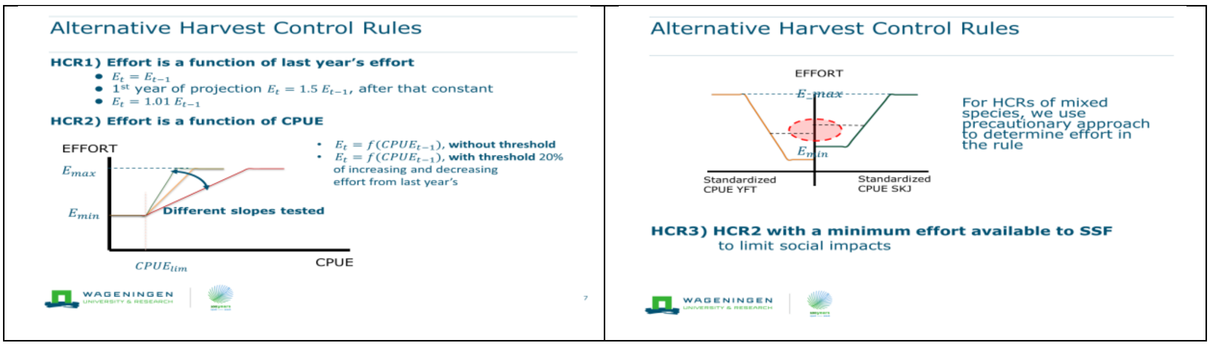

Figure 1. Alternative Harvest Control Rules (HCRs).

We use the relation between number of vessels and CPUE that resulted from simulation of operating model over 100 years and 1000 draws to estimate reference points of $CPUE_{max}$, $CPUE_{lim}$, and E_{max}. The highest value of CPUE ($CPUE_{max}$) occurs at the lowest level of effort (1 vessel). We assume that the minimum allowable CPUE ($CPUE_{lim}$) is at the $0.4CPUE_{max}$. Therefore, the E_{max} is the number of vessels that associated with $CPUE_{lim}$. We set 1000 vessels for the reference point of minimum effort (E_{min}) (HCR1 and HCR2).

We investigate the performance of the alternative HCRs with respect to aggregate rents, distribution of rents, and stability of fishing effort. Our tentative result (work in progress) show that the fishing rent increases monotonously during the projection years. Performance of HCRs on fishing rent show that in the effort scenario constant effort (HCR1a) has the lowest fishing rent, while both increasing effort scenarios (HCR2a and 2b) have the highest fishing rent. In this study, we assume that the poverty line is at Rp 25 million rupiah per year (1 US$ = Rp.14500,-). The distribution income in simulation of the effort scenarios (HCR1a-c) shows that the SSF's fishers get the biggest impact during the projection years with a high probability of falling into poverty. When the number of effort increases, the probability of earning less than Rp 25 million are even worse for MSF fishers (HCR1b and 1c). However, the LSF fishers has a zero probability of income below the poverty line in three effort-scenarios. The performance of distribution of income change for SSF and MSF fishers when we use last year's CPUE to determine total allowable effort. In HCR2a and 2b, SSF fisher's income have high probability of falling into poverty, however, the probability is slightly lower than those in effort scenarios (HCR1). In contrast, probability of MSF fishers earning below the poverty line is small in simulation of CPUE-based (HCR2a and 2b). The protection of SSF fishers (HCR3a and 3b) increases the risk of MSF and LSF fishers to fall into poverty than those in the CPUE-based scenarios. The protection on SSF reduces the probability of SSF fishers to fall into poverty. A good performance of HCRs on fisher's participation is shown in the three effort scenarios (HCR1a, 1b, and 1c), and in the CPUE dependent scenarios with restriction on changes in effort (HCR2b). For these scenarios, the number of vessels never fall into the minimum effort during the projection years. In the CPUE dependent scenario without restrictions on effort allocation change (HCR2a), there is a small probability of falling into the minimum effort. The greatest probabilities of the number of vessels falling to the minimum are shown in the CPUE driven scenarios with restrictions on the minimum number of SSF (HCR3a and 3b).

In this study, we show that HCRs that are CPUE-based maximize fishing rent. However, fishers participation during the projection years seem unrealistic (high inter-annual volatility in effort allocation). Performances of HCR with constant effort show that the implementation would be less efficient, then other scenarios however it is more realistic regarding fisher's participation. Protection of SSF would pay a price in terms of efficiency and shows a trade-off between fisheries in favor of SSF.

Table 1. Performances of alternative HCRs on fishing rent, income distribution and fisher's participation

Alternative HCRs	Fishing Rent (in Rupiah)	Risk of fishers earning <Rp 25×10^6/year (%)			Risk of effort fall below threshold (%)
		SSF	MSF	LSF	
HCR1a	1.82×10^{14}	96	2	0	0
HCR1b	2.18×10^{14}	96	89	0	0
HCR1c	1.97×10^{14}	96	51	0	0
HCR2a	2.59×10^{14}	94	2	0	4
HCR2b	2.59×10^{14}	94	2	0	0
HCR3a	2.43×10^{14}	4	40	90	82
HCR3b	2.39×10^{14}	4	40	91	90

4. Coupling commercial fisheries and survey data: a practical solution to boost the amount of information in data-poor context

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Quantitative fish stock assessment methods have become increasingly complex. However, the quality of available data may still restrict their applicability, being a particular concern in data-poor situations and where management decisions rely on either commercial fisheries or scientific survey data. In this study we address this issue by proposing a flexible statistical tool that can compare and integrate both datasets simultaneously, and hence boost the amount of information. Because of different sampling designs and procedures, distinct levels of biases arise between datatypes (e.g., different spatio-temporal coverages and size spectra of fish), which are accounted for in our model framework. The model is developed in Template Model Builder, alternatively applied to (i) commercial data, (ii) survey data and (iii) coupled datasets, and tested on cod, plaice and sprat stocks in the western Baltic Sea (2005-2016). We find that each data type supply different, yet complementary, information on the species spatio-temporal dynamics. Though the overall spatial pattern in both datatypes shows similar trends, the variability was clearly higher when evaluating the datasets separately, while the coupled dataset were most informative. This confirms that the predictive modelling was greatly improved by joining the datasets and will likely enhance future stock evaluation and management advice in both data-poor and data-rich contexts. Also, the current tool represents a valuable benchmark for fishery-based bio-economic management evaluation tools, provided that ecological-economic systems can be reliably mocked at a spatio-temporal scale that our model support and which indeed matters for robust management and policy makers.

Challenges in coupling commercial fisheries and scientific survey data

In many instances the quality and quantity of data dictates the analytical approaches that can be used for fisheries stock assessment. Most of the existing quantitative methods are heavily data driven and have been representing a challenge particularly for data-limited fisheries (Honey *et al.*, 2010). An intuitive alternative to overcome data shortages is to combine different fisheries data sources, *i.e.*, commercial fisheries and scientific survey data, and develop quantitative methods that can cope with their particularities. Rufener *et al*. (in prep) approached this issue by introducing a flexible and robust statistical model belonging to the class of point-process models (Negative Binomial Cox Process, hereafter NBCP), which can estimate and predict the abundance of fisheries target species while simultaneously considering environmental covariates that might shape a species spatio-temporal abundance and distribution.

As the sampling design underlying each data type follows their particular objectives, distinct levels of biases arise between them. For example, scientific survey data are usually considered of superior quality due to their statistically grounded sampling designs that also covers large marine areas (Fig. 1). Nevertheless, because they rely on expensive research campaigns, data are solely collected during a few weeks per year (Board, 2000; Rufener *et al*., in prep.) which in turn results in a certain degree of temporal bias. In contrast, commercial fisheries data forms the backbone of many stock assessment models and provide information all year long. However, because they are commercially driven, skippers deliberately choose fishing grounds that maximizes their target catches, and hence sampling locations tend to be aggregated in space (Fig. 1). The cornerstone in the development of such a model, thereby, is to account for such biases in order to provide the most reliable and robust abundance estimations. In Rufener's *et al*. (in prep.) proposed NBCP model, three additional bias sources have been acknowledged between both data sources and properly accounted, namely: difference in sampling effort, fishing catchability and trawled distance.

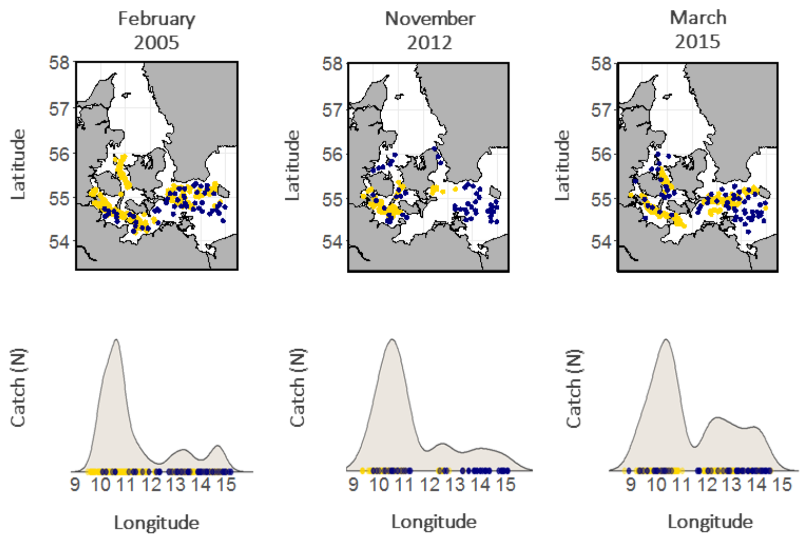

Figure 1: Example to illustrate the difference in the spatial and temporal positions of the scientific survey (blue dots) and fisheries commercial hauls (yellow dots,) during three different time frames for the Western Baltic cod stock. Lower panels represent the time-specific underlying cod abundance and highlights that commercial fisheries data tend to sample over areas with higher abundances.

Insights and future perspectives

The NBCP model was initially applied to the Western Baltic cod stock. As expected, the results suggested that both datasets provided different, yet complementary, information on cod's spatio-temporal dynamics (Fig. 2). By joining both data bases, it was shown that the estimation and prediction of cod's abundance was greatly enhanced and that the coupled model provided, in overall, a good balance between the spatial prediction of both datasets. The proposed model, thus, will likely boost future stock evaluations and provide better management advices for both data-poor and data-rich situations. Moreover, besides being flexible in regard to the input data and the different levels of bias corrections, the NBCP model represents a valuable benchmark because there is no need in changing existing sampling designs to meet the assumptions of some stock assessment models. Nevertheless, further improvements still need to be considered to better describe the fishermen's prevailed sampling (hence spatial bias correction), as it depends on many behavioral aspects that were not accounted in the NBCP model (*e.g.*, fuel consumption, fishing regulations and preferences for departing/landing port, etc.).

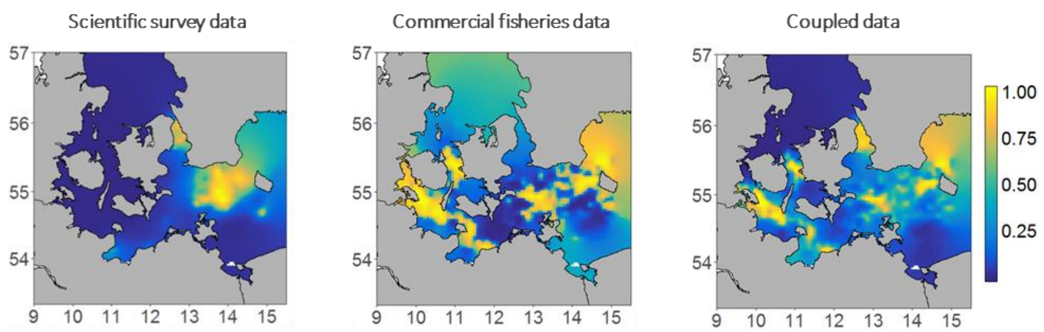

Figure 2: Snapshot of the Western Baltic cod (Age 3) abundance predicted by the NBCP model during the 1st quarter of 2016. For better visualization, abundances have been standardized.

Feedback, Views and Perspectives on Challenges from Stakeholders

5. Current challenges and perspective for fisheries management in EU

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This feedback presentation focus on three main challenges for EU fisheries management under the Common Fisheries Policy (CFP) also very much relevant in context of quota management for data poor stocks with new TAC setting for several of those stocks. The three issues cover i) New approach for Quota Management in the Common Fishery Policy (CFP); ii) Introduction and implementation of the landing obligation in the CFP; and iii) BREXIT (The UK decision to leave EU affecting extensive common fisheries areas). Management advice and resulting management measures for all stocks including data limited stocks need to take these main challenges into account when implementing them. This is especially the case for shared stocks and stocks involved in mixed fisheries.

UDENRIGSMINISTERIET, MINISTRY OF FOREIGN AFFAIRS OF DENMARK

NEW APPROACH FOR QUOTA MANAGEMENT IN THE COMMON FISHERY POLICY

- Until now: Total allowable catch (TAC's) was set for most stocks based on biological advice – for joint stocks after consultations with third countries and for autonomous EU stocks by EU.
- The sharing of fishing possibilities among Member States are based on fixed allocation keys (known as ”relative stability”).
- The latest reform of the CFP introduced the **new concept of Multiannual Plans (MAP's)**, which sets out rules for management of the main Stocks in a region.
- This involves setting the TAC for each of the main species based on ”a range of fishing mortalities”. This recognises that fishing at MSY is not possible for all stocks in a region at the same time. The ”upper range” can only be used under certain conditions.

UDENRIGSMINISTERIET, MINISTRY OF FOREIGN AFFAIRS OF DENMARK

INTRODUCTION AND IMPLEMENTATION OF THE LANDING OBLIGATION IN THE CFP.

- The 2014 reform of the CFP aims to gradually eliminate the wastefull practise of discarding unwanted catches.
- The CFP provides for the progressive phasing-in since 2016 of an obligation to retain and land all catches of species under catch limits from 1 January 2019.
- The Challenges is among others:
  - Compliance problems
  - Problems with ”Choke species”
  - No clear guidelines/practises established for the foreseen mitigating instruments such as high survivability, de minimis exemptions, inter-species quota flexibility and interannual-flexibility.

UDENRIGSMINISTERIET, MINISTRY OF FOREIGN AFFAIRS OF DENMARK

BREXIT – A NUMBER OF CHALLENGES

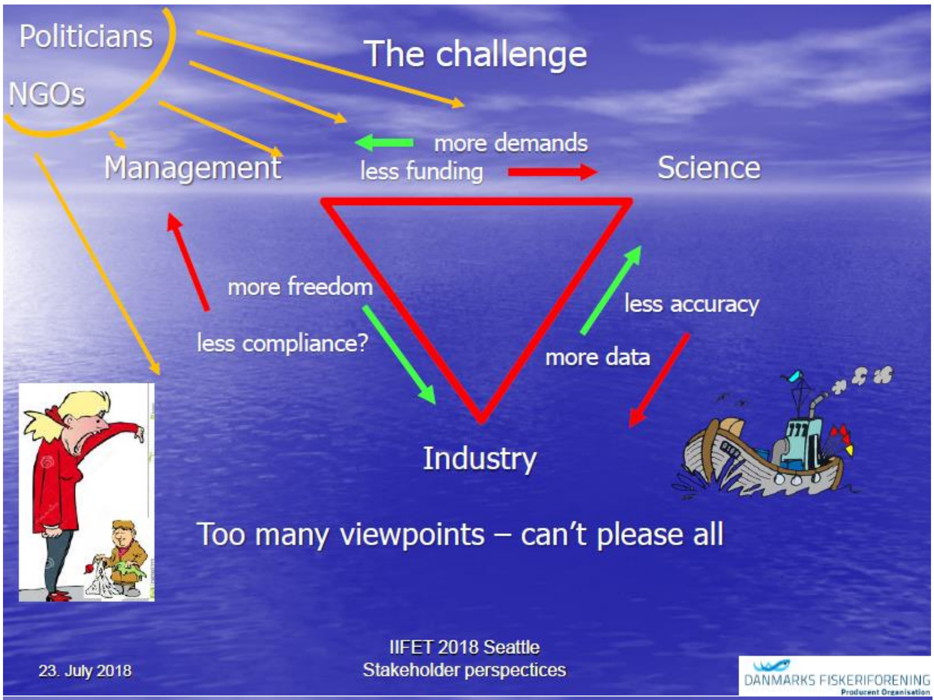
- When will it happen and what will be the impact:
  - 29 March 2019 (in case of ”Hard Brexit” without a deal) or end of 2020 (after the ”transition period” requested by UK)?
  - Will it bring changes in access to waters, allocations of quotas and access to markets – in the short or longer term?
  - Will EU and UK continue to have joint technical measures and what about control requirements?
  - Future set-up for management of jointly managed stocks between EU and UK and stocks which are also jointly managed with other third countries.

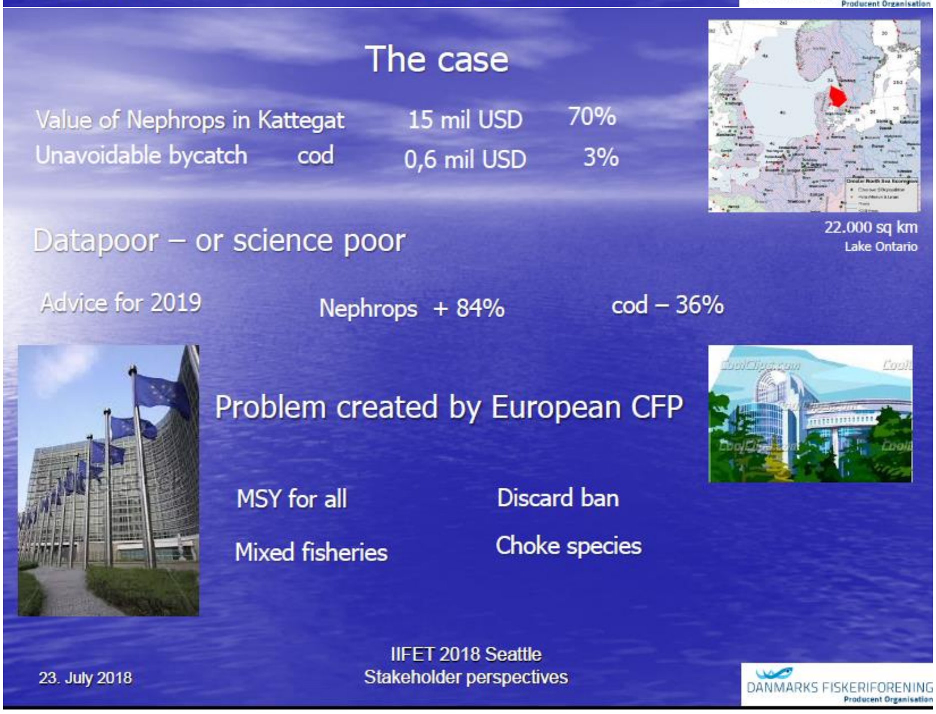
6. Challenges and Demands for Efficient Fisheries Management and Advice

Andersen, M.[1]

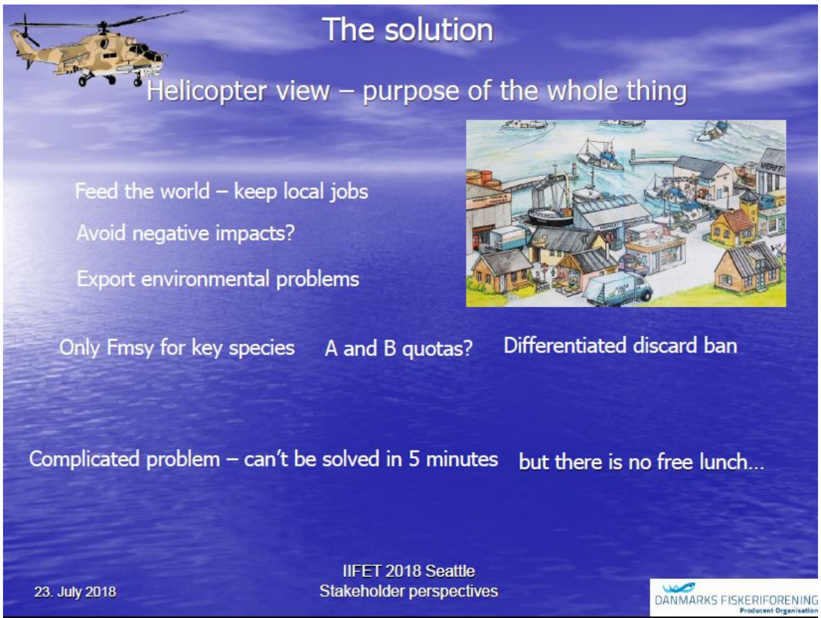
[1] Danish Fishermen Producer Organization (DFPO), Taulov, Denmark

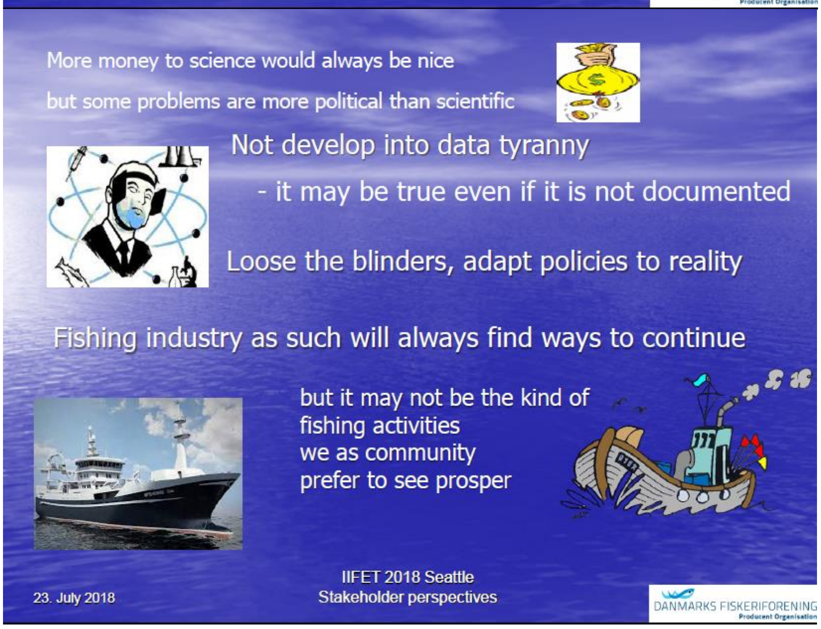
This stakeholder feedback presentation put emphasis on the challenge of managing data poor stocks efficiently taking into consideration the trade-offs between demands for more data, and accordingly involving information from more stakeholders, and the demands for precision in the data input and the resulting assessment and advice. This challenge is not becoming less when funding for providing information is decreasing.





Also, it highlights the challenges and contradictions introduced by EU with MSY management for all stocks and the discard ban creating among other choke species in mixed fisheries as well as the need for assessment of all stocks including data poor stocks. Most demersal fisheries in Europe exploit a mixture of many stocks, which do all not develop synchronously. Some increase and others decrease. Some are important for the industry and others less so. It is necessary to take those trade-offs and frame conditions into consideration in the necessary strategies to be developed for improving further implementation, application and integration of wider source and type fisheries information into management advice and management. This may especially be the case for data poor situations where such complementary and supplementary type of data and information are to a higher degree needed from a broader range of information sources than just traditional stock assessment and forecast data input. The work with data poor stock assessment methods like for example the SPiCT model described above, or other abundance estimation methods, is important, but should not stand alone. The results from the models should always be considered in a real world perspective. For example, there is some uncertainty in only using catch data, because they can in some cases be explained by political reasons.





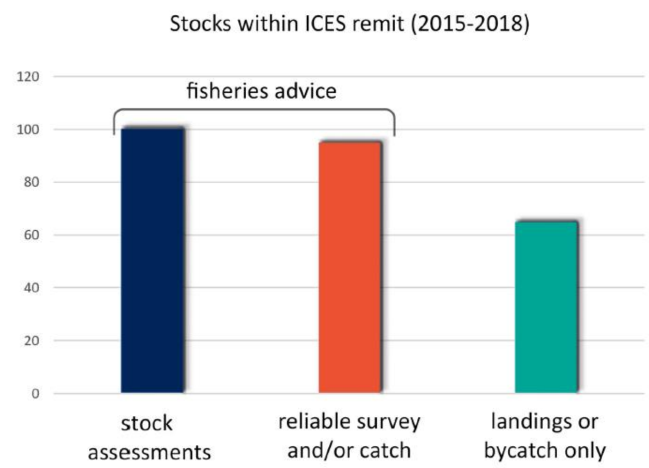
7. Data Limited Stocks in ICES

Dickey-Collas, M.[1]

[1] International Council for Exploration of the Sea (ICES), ICES Secretariat, Copenhagen, Denmark

This stakeholder presentation focused on the performance of data poor stock assessment models and their precision in assessment and forecasts used for fisheries management in the ICES area of the north east Atlantic. For many data poor stocks there are only landings and catch data available and this required methods to be used that have less precision and therefore a realization that precautionary rules are a crucial part of the advice. Any additional information can improve the performance of these methods (e.g. survey information, or knowledge of fleet dynamics).

Data limited stocks in ICES



Advice rules:

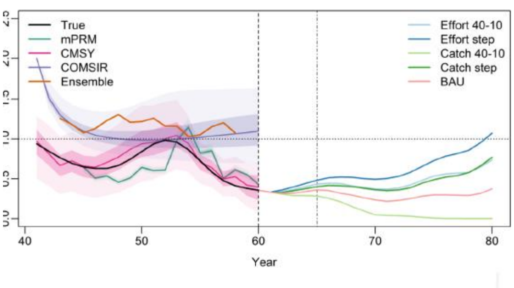
- *Forecasts*
- *Survey trends*
- *Length based proxies for MSY*

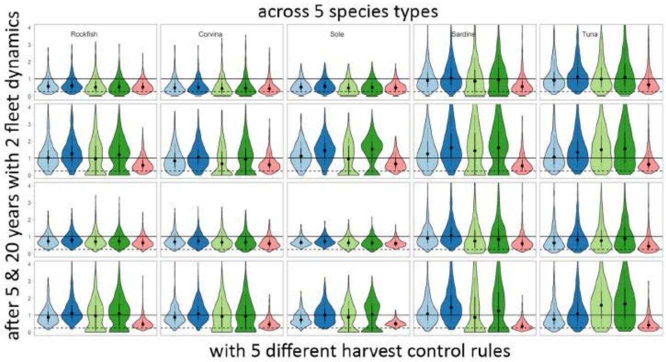
Providing management guidance for data-limited fish stocks with catch-only models & harvest strategies

ICES CIEM

Jessica Walsh et al (Fish & Fisheries 2018)

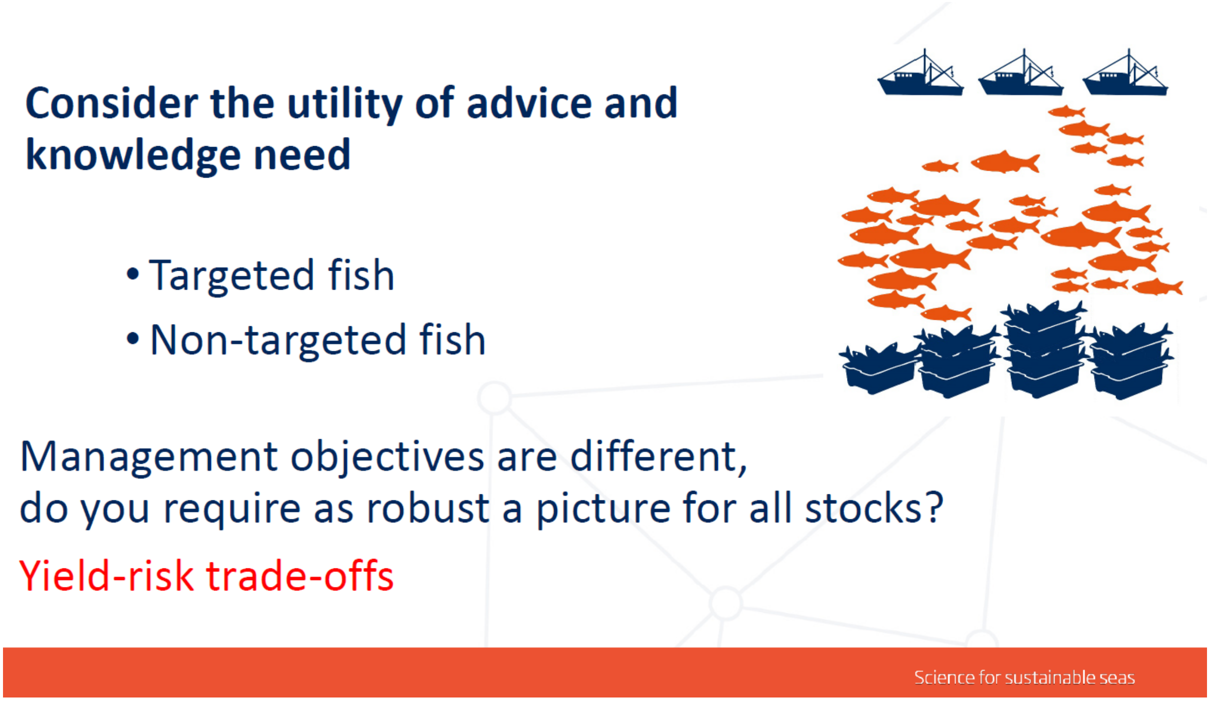
"catch-only superensemble models are not likely to provide reliable or practical management advice for most data-limited fisheries"





In a management advisory context the long term sustainability of exploitation must be considered in addition to short term operational objectives. ICES is using the SPiCT model (as described above) and is assuming that uncertainties for long-term prognosis are status quo, in the absence of other information. The SPiCT model developers do not recommend long term prognosis with the model, and this is the challenge when using the model in an operational context. ICES interprets the precautionary approach as ensuring that there is a less than 5% chance of management action resulting in a stock going below the biomass reference point Blim. This has not been fully tested with SPiCT and ICES is challenged to find a way to estimate Blim and provide advice that can be considered precautionary in data poor situations. This needs to be clarified to provide robust management advice, and there is an ongoing ICES working group dealing with these issues and problems.

There is also a trade-off required between data required and management advice. Many fisheries in the ICES area are mixed, especially now with the landing obligation. Do we need MSY for these stocks? The feedback from the audience also put emphasis on the trade-offs in the need and utility of MSY advice for all stocks compared to the knowledge basis needed for providing robust assessment and advice. It is a question whether an equally robust assessment and advice according to MSY are needed for the targeted stocks and for the non-targeted stocks. It is likely that the management objectives are different for the different types of stocks. These trade-offs need to be carefully considered in relation to providing robust and efficient advice taking into consideration the complexity of the real system and providing overall efficient and transparent management advice. Also, specific ICES working groups are dealing with those challenges.



8. Use of Proxy Target Reference Points in Data Poor Fisheries

Pascoe, S. [1], Hutton, T. [1], and Thebaud, O. [2]

[1] CSIRO Oceans and Atmosphere, Queensland Biosciences Precinct, St. Lucia, QLD, Australia
[2] Unité d'Economie Maritime, AMURE French Research Institute for Exploitation of the Sea, Ifremer, Plouzané, France

Australian Commonwealth fisheries management has a key objective of maximising the net economic return from the fishery resource. This is interpreted as achieving maximum economic yield (MEY). For multispecies fisheries, MEY is considered to be the level of effort, catch and biomass that maximised economic profits over the fishery as a whole.

In an ideal world, target reference points such as the level of catch and/or effort that can lead to MEY can be estimated using bioeconomic models of the fishery. In reality, most fisheries do not have such a model. In many fisheries where bioeconomic models do exist, these are generally not of sufficient robustness to estimate tactical targets for the fishery, but have been developed to provide more strategic advice to managers (i.e. assess which management option may produce the most benefits, without having an exact estimate of these benefits or the exact levels of catch and effort that will achieve them).

To counter this, the Australian Commonwealth Fisheries Harvest Policy (Department of Agriculture and Water Resources, 2018) has proposed using generic proxy target reference points for biomass when more "appropriate" information is not available. The current default target for primary species is $B_{MEY}=1.2B_{MSY}$ when B_{MSY} is known, or alternatively $B_{MEY}=0.48B_0$. For secondary species, the proxy target reference point is $B_{MEY}>B_{MSY}$, or $B_{MEY}>0.4B_0$.

Several studies have recently been undertaken to assess whether these proxy target reference points are appropriate, especially in multispecies fisheries, or if better proxy targets can be generated using "generic" bioeconomic models using the key characteristics of the fishery and species. Pascoe *et al.* (2014) estimated a range of alternative target reference points for data poor single species fisheries, while Pascoe *et. al.* (2015) estimated proxy target reference points using two approaches (one based on regression trees and the other using Bayesian Networks (Figure 1) for multispecies fisheries. Details on these approaches are provided in the respective cited papers.

The approaches were compared using a long run equilibrium bioeconomic model of the trawl component of the Southern and Eastern Scalefish and Shark Fishery, a multispecies fishery. The bioeconomic model was also used to derive the "best" estimates of the target reference points from a data rich environment. Random error was applied in the simulations to assess how well the different approaches worked in an uncertain environment. The model was estimated as a goal programing model, with the goals being to have the biomass of each species to be at each level as defined by the target reference point, and also maximize economic profits. The divergence from these goals (measured as a relative proportion) was used as the measure of performance, with a zero divergence indicating that all goals were simultaneously achieved.

From the results (Figure 2) the bioeconomic model based measures of the target reference points had the tightest distribution around the "true" measure, as might be expected. The BBN and Regression Tree approaches also worked reasonably well, with most outcomes being close to the optimal (i.e. a zero divergence). For the current target reference points (i.e.

$1.2B_{MSY}$), however, the model was unable to simultaneously achieve the target reference points for the different species, and the level of divergence from the goals was substantial.

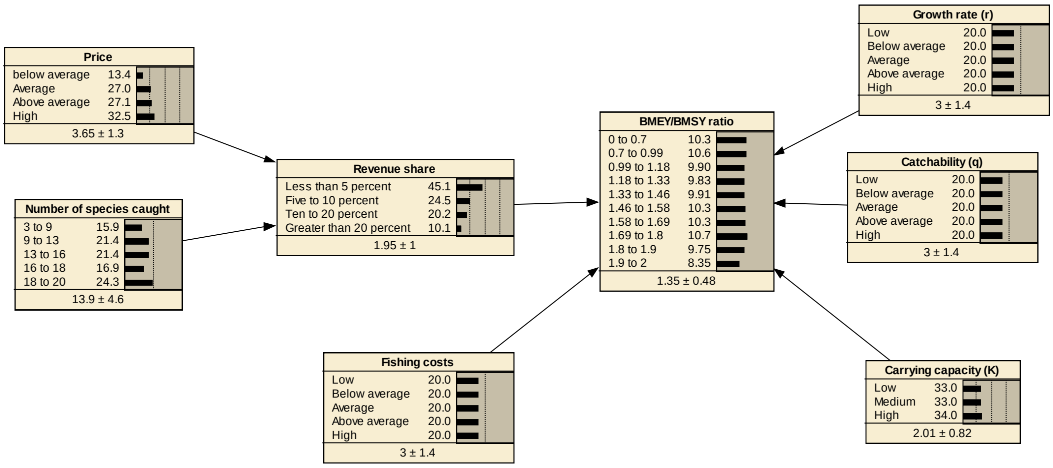


Figure 1: BN model for estimating target reference points for data poor multispecies fishery

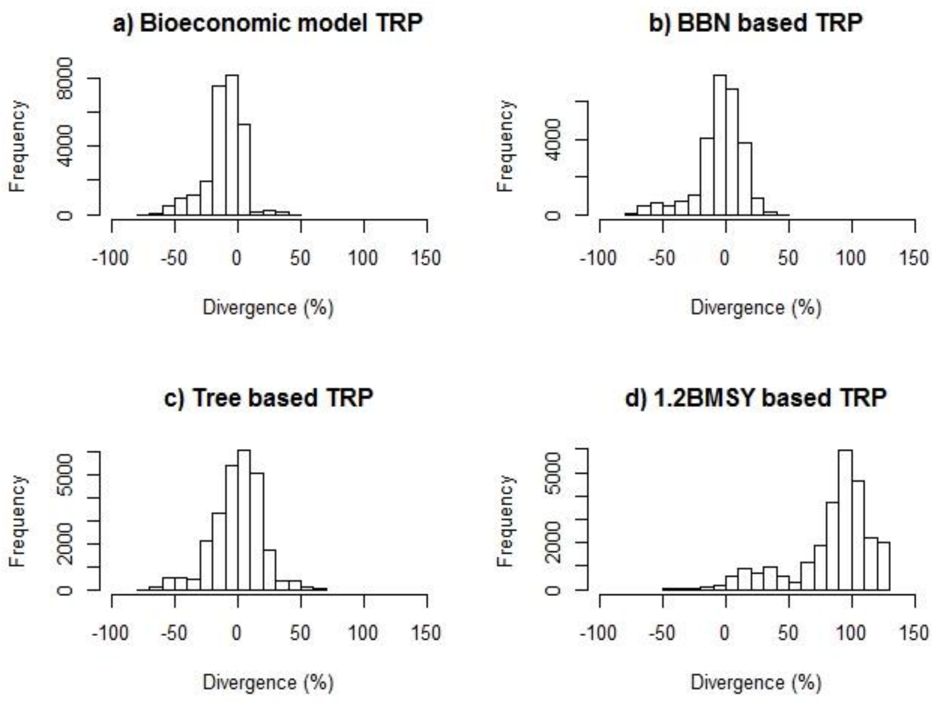


Figure 2. Distribution of estimated economic profits using different approaches to estimating target reference points

The results of the study suggest that proxy values of target reference points can be derived that provide a reasonable estimate of the true target reference points for data limited fisheries. However, the use of a single value applied to all species is not feasible, and can result in the targets not being achieved. More recent analysis suggests that it may not be necessary to apply target reference points to all species in a multispecies fishery, with substantial benefits being realized by focusing on only the main species (Pascoe et. al., 2018).

9. Doomed to Dealing with Data Limitations?

Thebaud, O.[1], Briton, F. [1], and Macher, C. [1]

[1] Unité d'Economie Maritime, AMURE French Research Institute for Exploitation of the Sea, Ifremer, Plouzané, France

In this presentation, the focus was on the need for robust methodologies to deal with data limitations in fisheries assessments, even in contexts that are considered data-rich. This is considered important for two key reasons:

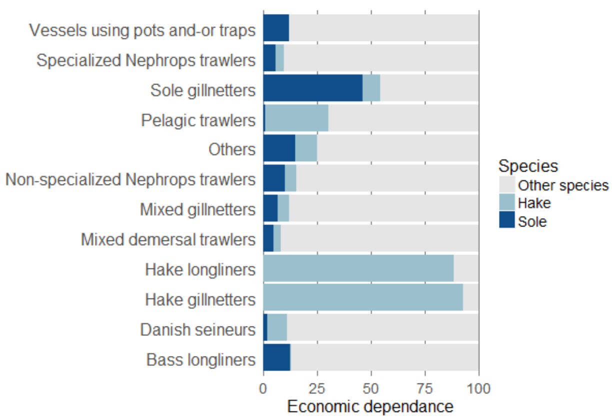
- first, there is a need to ensure that the analysis of alternative management strategies incorporates all key drivers of the ecological, economic and social health of fisheries systems;
- second, it is important to apply adequate levels of precaution when faced with uncertainty regarding important components of these systems, hence to develop comprehensive bio-economic assessments.

The call for an ecosystem approach to fisheries management has progressively broadened the scope of the ecological and economic components that need to be incorporated in fisheries science and advice. In catch-based management systems, this has led to the development of more comprehensive catch-quota management systems, which aim to include most if not all the species and stocks on which a fishery has an impact. In mixed fisheries models supporting management advice, this implies accounting for variable numbers of species entering into the catch composition and revenue of fishing fleets, alongside a small number of key commercial stocks which have historically been studied and for which stock assessments are available. In the absence of specific information, the catch from the less well known species is often considered as exogenously determined, with constant catch rates, or at best, the inclusion of trends in catch rates over time, reflecting the limited understanding of underlying biomass status and dynamics.

Being (seriously) integrative in our ecological-economic scenarios

Ecosystem approach → more comprehensive catch-quota management systems

Example: economic consequences of a restoration strategy in the Bay of Biscay mixed fishery



Improved biomass (of target species):

→ increase in catch rates
→ reduced effort to reach quota
→ reduced catch of "static species"
→ reduced returns

i.e. potentially counter-intuitive results!

So:

- How much can/should the model be expanded?
- For the remaining "data limited components", what reasonable assumptions can/should we make?

→ Go see F. Briton's presentation!

2

In the example presented above, a bio-economic model of the Bay of Biscay mixed demersal fishery is developed, with two key commercial stocks (sole and hake) that can be modeled explicitly using available stock assessment information (Macher et al., 2018; Briton et al., under review). The revenue of the fleets however mainly depends on the catch of a large number of other jointly caught species, with wide variation across fleets. Management strategies entailing a recovery in the two key stocks would lead to an increase in the catch rates of these two species, and an ensuing reduction in the levels of nominal fishing effort required to catch the quotas of these two species. Such an effort reduction would mechanically lead to a reduction in the catch of the “other species”, and paradoxically, to reduced returns for the fleets where these other species have a strong impact on fleet returns.

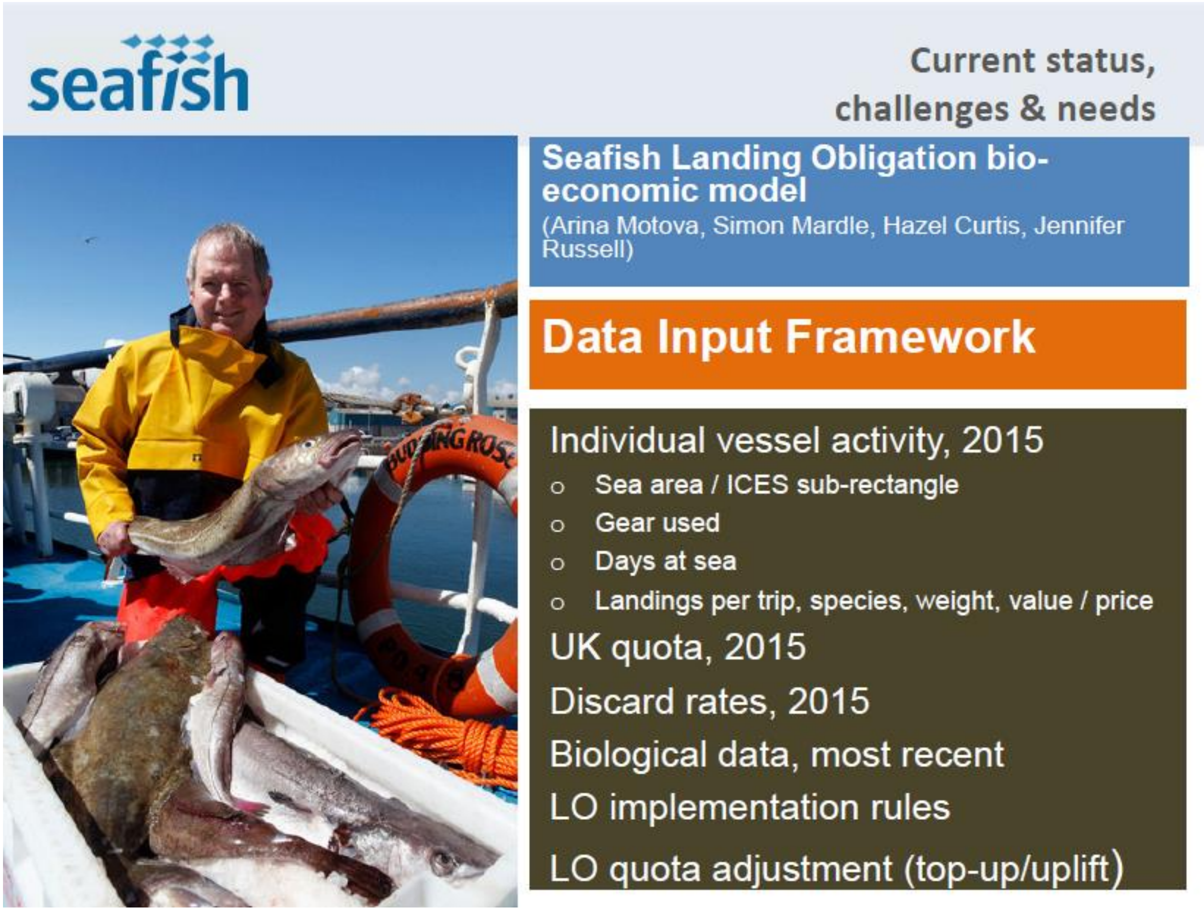
To avoid such counter-intuitive results, efforts are needed to expand the scope of the models used to assess such fisheries systems. Key questions relate to the extent to which dynamic models of stock biomass can and should be expanded to include the potential response of other species to changes in fishing effort, as well as the potential effort reallocation by fleets resulting from changes in relative catch rates of the different species. But it also seems crucial to develop robust approaches on which to base the predicted responses of both fish stocks and fishing effort, where the time and resources available do not allow the development of such detailed models, and to explore how these approaches could be integrated into the standard bio-economic assessment framework. Of particular importance when doing so is the way in which levels of uncertainty regarding the predicted responses for different stocks and fleets can be accounted for in developing management strategy evaluations, to adequately assess trade-offs between ecological and economic risks of alternative management strategies.

10. Availability of economic data for models to explain and inform management decisions for commercial fishing.

Curtis, H.[1]

[1] Seafish Scotland, Edinburgh, UK Scotland

This feedback stakeholder presentation has focused on the availability of data informing fisheries management decisions with special emphasis on economic data for commercial fishery. A row of aspects need to be taken into consideration for obtaining information and data that can be efficiently integrated into management advice and the decision making process.



seafish

Future perspectives

Well-informed decisions more likely to give desired outcomes

Business & policy decisions

Marine environment creates difficulties not seen on land

Fisheries independent data is costly – industry as data collection platforms, involve in science, improve buy-in

seafish

Future perspectives

Online impact assessment tools

Simulation / optimisations

Seafish fleet enquiry tool

Seafish LO bio-economic model

Ability to set parameters & modify assumptions

Can do much more than provide information

Could transform stakeholder relationships in fisheries management if used well

11. Stock Assessment and Economic Analysis Challenges for Management Strategies of Data Poor Stocks: Northeast Region of the United States

Thunberg, E.[1]

[1] NOAA Fisheries, Northeast Fisheries Science Centre, Social Sciences Branch, Woods Hole, MA, USA

This stakeholder feedback session focused on the available data and methods to assess stocks where data are limited and the implications for the types of economic analysis these limitations present for informing management strategies in the Northeast region of the United States. In the Northeast region data poor stocks have been assessed through what is called the Data Poor Stock Working Group where the most recent assessment was undertaken during 2009 for wolffish, skates, monkfish, black sea bass, and red crab. In many respects the available data for these assessments were similar to that for species with analytical assessments but an analytical assessment had not been accepted or data for some key biological characteristic was missing. This means that what separates a"data poor" stock from others may not necessarily be lack of data. NOAA Fisheries does have standard assessment methods that have been implemented on a Nation-wide basis through the NMFS Fisheries Stock Assessment Toolbox.

Economic analysis of fishery management actions in the Northeast region for data poor stocks are not necessarily limited by available data. The primary data sources that support economic analysis include mandatory vessel trip reports, mandatory seafood dealer reporting, VMS units are mandatory for many key fisheries, and trip cost data are collected through the on-board observer program. This means management actions that may be needed to reduce landings of data poor stocks can be done. Unfortunately, without the capability to project changes in stock size it is difficult to determine by how much landings need to be reduced and it is not possible to conduct a benefit-cost analysis of rebuilding plans. This also means that the capability to build coupled biological-economic models is limited.

Conclusions, Challenges and Future Perspectives

Some recent developments

Many current assessment methods for data limited fish stocks suffer from several short comings, such as assuming equilibrium, constant carrying capacity and productivity, over-simplifying biological processes and ecological interactions, ignoring fishing gear selectivity, being subject to non-representative sampling, and lacking quantification of assessment uncertainty. Incorporation of stochastic data-limited assessment methods into management strategy evaluation when estimating some of the above parameters and taking into account uncertainty will better reveal appropriate harvest control rules taking into account assessment uncertainty. Also, tools which allow modeling of time variant (e.g. seasonal) and stock stage based dynamics and patterns in productivity may be more realistic without requiring more data.

Furthermore, several data limited stock assessments suffer from not taking into consideration the integrated monitoring (data collection), assessment and management context and needs in which they are performed. Robust interview based frameworks addressing the above among stakeholders provides standardized formats and analytics for exploring assumptions and available options and draft harvest control rules and management strategies to be evaluated. Implementation of such frameworks and feasible systems will increase transparency and quality of the methods and systems used to evaluate assessment results, as well as improve the basis for making tactical and strategic decisions.

Many developing countries fisheries management need to consider many other goals than rents maximization such as distribution of rents and employment. Simulation frameworks to perform scenario and management strategy evaluation to enable this are needed, also under data poor conditions. As a contribution to this, a stochastic bio-economic model has been implemented to combine dynamics of an age-structured production model and the economic performance of fishing activity and characteristics at three different scales to evaluate performance of alternative harvest control rules (HCRs). The performance of different HCRs and fishing levels are here evaluated with respect to aggregate rents, distribution of income, and stability of fishing effort, also including evaluation of probability for fishers to fall into poverty.

The quality and amount of available data often severely restrict the applicability of assessments, being a particular concern in data poor situations and where management decisions rely on either commercial fisheries or scientific survey data. Consequently, flexible statistical tools and model frameworks that can compare and integrate both types of data simultaneously are highly needed. To meet this need, a flexible and robust statistical model belonging to the class of point-process models (Negative Binomial Cox Process, NBCP) has been developed and implemented which enables abundance estimation from both coupled and individual data types. It accounts for the different sampling designs and procedures, distinct levels of bias, and different spatio-temporal scales of the data types. It is apparent that the precision of estimates and predictive power of abundance increase when combining the data types. The model will likely boost future stock evaluations including bias corrections, precision, and improved sampling designs also evaluating the cost-effictiveness of those.

In Australia, a key objective is to maximise the net economic return from the fishery resource which is interpreted as achieving maximum economic yield (MEY). For multispecies fisheries, MEY is considered to be the level of effort, catch and biomass that maximised economic profits over the fishery as a whole. In many multi-species fisheries bio-economic models do not exist to estimate precise tactical target reference points by species, and it has been investigated whether generic proxy target reference points for biomass could be established by more generic bio-economic models using key characteristics of the fishery and species. The results suggest that proxy values of target reference points can be derived that provide a reasonable estimate of the true target reference points for data limited fisheries. However, the use of a single value applied to all species is not feasible, and can result in the targets not being achieved. However, recent analysis suggests that it may not be necessary to apply target reference points to all species in a multispecies fishery, with substantial benefits being realized by focusing on only the main species.

In the Northeast region data poor stocks have been assessed through the Data Poor Stock Working Group. In many respects the available data for these assessments are similar to that for species with analytical assessments, but the analytical assessment has not been accepted for various reasons. This means that what separates a “data poor” stock from others may not necessarily be lack of data. Economic analysis of fishery management actions in the Northeast region for data poor stocks are not necessarily limited by available data. The challenge lies in the lack of models adequately capable of projecting changes in stock size with the needed accuracy and certainty.

Challenges and further perspectives

There is a major challenge of managing data poor stocks efficiently in relation to the trade-offs between demands for more data, and accordingly involving information from more stakeholders, and the demands for high certainty and precision in the data input and the resulting assessment and advice. This challenge is not becoming less when funding for providing information is decreasing. There is not invested adequate resources into obtaining standardized data input from stakeholders with adequately high quality control check. Accordingly, the situation becomes not only data poor but also science poor. A row of aspects need to be taken into consideration for obtaining information and data from stakeholders that can be efficiently integrated into management advice and the decision making processs. Establishment of standardized data input frameworks covering among other industry data as supplement to expensive fisheries independent data, as well as online impact assessment tools to simulate scenarios for and/or optimize data use, could likely improve this situation. This could potentially transform stakeholder relationships in fisheries management if used well.

Several studies indicate that data poor stock assessment methods and models only including landings and catch data are less precise and accordingly realization that precautionary rules are a crucial part of the advice. Any additional information (e.g. research survey information or knowledge of fleet dynamics) will improve the performance of these methods.

The management of data poor stocks very much face the challenges of mixed fisheries and discards in relation to lack of assessment of all exploited stocks covering especially by-catch species. For example, the implementation of the current EU fisheries management with quota management for data poor stocks with new TAC setting for several of those stocks, the landing obligation, and the concept of multiannual plans put focus on this. Stocks in mixed fisheries does not develop synchronously, some increase others decrease. Also, the stocks have very different fisheries and ecosystem importance. Additionally, a row of other important problems with compliance to regulations and “choke species” are also faced, and a future need for clear guidelines/practices to be established for the foreseen mitigating instruments such as high survivability, de minimis exemptions, inter-species quota flexibility, and inter-annual flexibility is apparent. A central question is, whether all stocks need to be managed according to MSY (Fmsy) and single stock TACs based on yearly single stock assessment basis. Is it possible to fish at MSY for all species/stocks at the same time? And is an equally robust assessment and advice according to MSY needed for the targeted stocks and for the non-targeted stocks? Trade-offs and frame conditions need to be considered in the necessary strategies to be developed for improving further implementation, application and integration of wider source and type fisheries information into management advice and management.

The call for an ecosystem approach to fisheries management has progressively broadened the scope of the ecological and economic components that need to be incorporated in fisheries science and advice. There is a need to ensure that management strategy evaluation and data poor stock assessment methodologies incorporates all key ecological, economic, and social drivers of the fisheries systems, and it is necessary to apply adequate levels of precaution according to uncertainty in the drivers. Key questions relate to the extent to which dynamic models of stock biomass can and should be expanded to include the potential response of other species to changes in fishing effort, as well as the potential effort reallocation by fleets resulting from changes in relative catch rates of the different species.

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[*1] IIFET: The International Institute of Fisheries Economics & Trade.
[*2] ICES: International Council for Exploration of the Sea.
[*3] UNCLOS III 1982: United Nations Convention on the Law of the Sea w. follow up in the Johannesburg 2002 Declaration.
[*4] PICES: North Pacific Marine Science Organization.
[*5] NAFO: North West Atlantic Fisheries Organization.
[*6] FAO: Food and Agriculture Organization of the United Nations.