Coordinator’s Welcome

The European Common Fisheries Policy has made a commitment to direct management of fish stocks towards achieving Maximum Sustainable Yield (MSY). In the Myfish project, we address the challenges arising because achieving MSY for an individual stock may hamper the achievement of MSY for other stocks and compromise ecological, environmental, economic, or social aims. The objective is to face these difficulties and provide definitions of MSY variants, evaluations of the effect and desirability of attaining these variants, and an operational framework for their implementation. This is achieved through case studies addressing single species, mixed species, pelagic, and demersal fisheries across Europe. Social aspects are integrated throughout the project by active involvement of stakeholders in the definition and evaluation of MSY variants.

Over the past three years, the project participants have made a dedicated effort to provide the scientific input needed by the European Commission to construct Multiannual Management Plans aiming at MSY using a series of descriptions of the consequences of aiming at different MSY options. For example, aiming at MSY for all species individually will lead to choke species problems as the fishing effort required to reach MSY of the most sensitive species is less than that required to achieve MSY of more robust species. This issue has become increasingly relevant with the gradual implementation of the landing obligation for a number of species. The efforts have included discussions with stakeholders in all regions about the pros and cons of aiming for different MSY options.

We take this opportunity to report the most significant advances made to in relation to evaluating the trade-offs required and the preferences for different implementations of MSY management. This newsletter describes examples of work conducted in each of our five regional studies: the Baltic Sea, Mediterranean Sea, North Sea, Western Waters and Widely Ranging. Each region presents examples of trade-offs predicted from scientific models. These trade-offs are intended to inform managers and other stakeholders of the likely benefits and disadvantages resulting from aiming for different options within the MSY framework. We hope you will enjoy the newsletter and feel that it adds to your knowledge.
Project background

Myfish decomposes MSY into three aspects: What to maximise (MSY variants), what to sustain (constraints to sustainability) and how to manage isheries aiming for MSY (management measures). The project was initiated with a workshop aiming to determine which variants are acceptable and feasible in practical management in each of five European regions: the Baltic Sea, the Mediterranean, the North Sea, the Western Waters and Widely Ranging Stocks. The results showed that the variant ‘Maximise inclusive governance’ had a ‘very good’ performance in all groups, making this the top ranked variant together with variants of MSY and MEY. Ensuring precautionarity was an important aspect in all areas.

As a result, Myfish has continued to produce test cases for how the inclusive governance process can be conducted in practice while adhering to the precautionary and MSY principles. The work has involved various aspects of scientific modelling to predict what aiming for different MSY variants such as MSY in tonnes or value of landings would mean to the yield, the status of stocks and the status of other factors such as other ecosystem components and income associated with ishing, visualisation and elicitation of responses to different scenarios.

The results of the work are reported in Decision Support Tables (DSTs) in this newsletter. DSTs are graphical tables reflecting the effects and trade-offs of implementing different MSY options on ecosystem, economic and social constraints with a particular focus on the risk of exceeding acceptable levels for constraints. The goal of the DSTs is to convey a large amount of information on alternative management scenarios in an accessible manner, making it more understandable to fisheries stakeholders. The involvement of stakeholders in the Myfish project and their feedback is an integral component of the development of the project. DSTs have been used to present the results of the project to stakeholders in all regions. More information related to the details of the models used to produce the tables can be found at the Myfish website www.myfishproject.eu/project-myfish/deliverables.

Myfish Decision Support Tables (DSTs)

The Myfish DSTs integrate a number of graphical devices: (1) icon arrays which also incorporate ‘fading out’ to represent uncertainty; (2) icons that closely resemble the actual species concerned; (3) different types of icons to represent different quantities, fish stock or profit; (4) colour to show regions of particular concern and (5) embedded pie-charts to show progression or difference. The number of cod icons refers to the mass of cod, the number of Euro signs to profit, the colour red to problems, and fading to uncertainty. The goal is to convey a large amount of information in a manner which makes comparison across several criteria of the merits of alternative management scenarios more accessible to stakeholders than would be achieved with a table of numbers. The models behind the DSTs have all been assessed against predefined criteria and details on the results can be found in the end of this newsletter.

Authors: Christine Shortt, Adrian Leach, Polina Levontin, Paul Baranowski and John Mumford.
Case Study 1: Baltic Sea

Introduction

In the Baltic Sea case study, we address the trade-off between recovery of Atlantic cod versus the health of the ecologically important forage fish sprat and herring. These fish stocks are closely connected by strong ecological interconnections between the species, as cod is preying on both herring and sprat. Thus, fluctuations in the size of the cod stock relate to changes in natural mortality rates of sprat and juvenile herring. Besides being of direct commercial interest, forage fish species have an enormous indirect value as a primary food source for many marine predators. In the Baltic Sea, sprat has a key role in the food-web as prey for cod, as well as marine mammals and seabirds. Hence, depleting the sprat stock bears unforeseeable risks for ecosystem functioning, service provision and protection of species. Substantial difficulties have arisen in the Baltic cod single species assessment over the past few years, presumably due to a range of factors such as reduced growth, changes in catchability and increased predation. In the following analyses, the assumption is that the difficulties encountered in recent years are transient phenomena and hence will not affect long term considerations. Under these assumptions, the Baltic cod recovery plans raise two fundamental fisheries management questions involving trade-offs: (i) How much biomass and potential economic yield, provided by the high value cod stocks, needs to be sacrificed to allow for the protection of lower value, but ecologically important, forage fish species, and (ii) What are the additional costs of considering an equitable distribution of benefits between the demersal (cod) and pelagic (forage fish) fisheries sectors, given that the latter has expanded after the cod collapse?

Author: Rudi Voss

DST Description

The DST for the central Baltic Sea, takes into account species interaction (i.e. cod predation on herring and sprat). The table shows two potential management options and their respective outcome for cod, herring and sprat in terms of spawning stock biomass (SSB, thousand tonnes), catch (thousand tonnes), total profits (million €), distribution of profits to the fisheries, as well as fishing mortality. Options are chosen to achieve a limit sprat spawning stock biomass of 410,000 tonnes, i.e. respecting current Blim values applied in the management. Management decision background: Total quotas are set annually for each species; distribution to country follows the ‘relative stability principle’; the path towards each MSY option differs depending on constraint(s).
### Baltic Sea management DST

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Catch/SSB kT</th>
<th>Total Profit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sprat</td>
<td>Herring</td>
</tr>
<tr>
<td>MEY with no constraint</td>
<td>76/240 kT</td>
<td>160/1000 kT</td>
</tr>
<tr>
<td>Gini index = 0.49</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MEY with high Sprat conservation</td>
<td>41/570 kT</td>
<td>170/1000 kT</td>
</tr>
<tr>
<td>Gini index = 0.48</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MEY with equity and high Sprat conservation</td>
<td>200/570 kT</td>
<td>240/1200 kT</td>
</tr>
<tr>
<td>Gini index = 0.70</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**KEY**

- Sprat $= 50$ kT
- € $= €10,000$
- SSB at $B_{msy}$ or above
- SSB at $B_{lim}$
Case Study 2: Mediterranean Sea

Introduction

The Mediterranean case study includes two sub-cases that examine the multi-species bottom trawl fisheries exploiting the demersal resources of the Aegean (eastern Mediterranean) and Balearic (western Mediterranean) seas. The medium term effects of various input control management measures on economic MSY variants were examined taking also into account biological (i.e. exploitation state of key-stocks) and social constraints (sustainability of the jobs in the fisheries sector). The DSTs shown below summarise the comparisons among those management measures that, depending on the case, include various fishing effort control schemes in the form of temporal closures and capacity reductions, as well as changes in the selectivity pattern of the fishing gears.

Authors: George Tserpes, Christos Maravelias, Antoni Quetglas, Pere Oliver, Enric Massutí, Manuel Hidalgo, Santiago Cerviño, Paz Sampedro

Eastern Mediterranean DST Description

In the eastern Mediterranean case study, the multi-species bottom trawl fisheries that exploit the demersal resources of the Aegean Sea were considered. The medium term effects of various input control management measures on economic MSY variants were examined, taking into account biological (i.e. state of key-stocks) and social constraints (sustainability of the jobs in the fisheries sector). The DSTs summarise the comparisons among temporal closures, capacity reductions and gear selection changes. Effort reductions implied through temporal closures seem to be the more realistic scenario as they seem to improve profits per vessel, satisfying, to a large extent the biological and social constraints. Drastic capacity reductions would decrease the ecosystem impact of the fisheries and also lead to high profit increases in the medium term, but subsidies may be necessary for their application.
## Case Study 2: Mediterranean Sea

### Eastern Mediterranean DST

#### East Mediterranean DST

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Hake Conservation</th>
<th>Profit Per Vessel Per Year</th>
<th>Viability of fishery</th>
<th>Employment</th>
<th>Dependence on Subsidies</th>
<th>Ecosystem impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Yield F=0.56</td>
<td>Unsafe</td>
<td></td>
<td>€ 0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MEY respecting biological contraints F=0.50</td>
<td>Optimal</td>
<td>€40,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capacity Reduction F=0.45</td>
<td>High</td>
<td>€105,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improved Selectivity F=0.53</td>
<td>Unsafe</td>
<td>€25,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### KEY

- **€** = €10,000

<table>
<thead>
<tr>
<th>Score on a five point scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 very bad</td>
</tr>
<tr>
<td>2 bad</td>
</tr>
<tr>
<td>3 medium</td>
</tr>
<tr>
<td>4 good</td>
</tr>
<tr>
<td>5 very good</td>
</tr>
</tbody>
</table>
The Western Mediterranean DST addresses the management of demersal species exploited by the bottom trawl fishery, which is the most important in terms of total landings in the Balearic Islands. Although these fisheries are clearly multispecific, four target species can be considered corresponding to four different fishing tactics representing the exploitation of different depth strata: 1) striped red mullet, *Mullus surmuletus* (Shallow Shelf); 2) hake, *Merluccius merluccius* (Deep Shelf); 3) Norway lobster, *Nephrops norvegicus* (Upper Slope); and 4) red shrimp, *Aristeus antennatus* (Middle Slope). These four species are regularly assessed in the framework of the GFCM or STECF and, although in better exploitation status than in nearby areas, all four stocks are overexploited.

The DST includes three different scenarios: 1) the current situation, which is considered unsustainable given that all four stocks are over-exploited; 2) the MSY predicted by the bio-economic model, which is considered unfeasible by the fishermen owing to the very high reductions in fishing effort required (up to 71% for hake); and 3) an intermediate scenario in between these two previous, extreme situations; although this intermediate scenario also demands important effort reductions, they are considered feasible by the fishermen.

The main management scenario agreed with stakeholders includes the reductions of fishing effort shown in the intermediate scenario. The benefits of such fishing effort reductions would be twofold. Firstly, an improvement in the exploitation status of the different target stocks and hence on the demersal ecosystems exploited by the bottom trawl fishery. Secondly, an improvement in the viability of the fishing industry by means of reducing fishing costs in terms of substantial reductions in fuel consumption. For fishermen, the fuel price is the main constraint.

Given that bottom trawlers operate on different bathymetric strata depending on the target species, differential effort reductions should be put in practice according to the exploitation status of each single stock. As hake is the most over-exploited species, effort reductions should be higher on its fishing grounds (deep shelf). For hake, even a recovery plan should be considered.

The effort reductions should be in terms of hours per day or days per week. For fishermen, the most useful option would be reducing the days per week, which would also result in a considerable reduction of fuel consumption. Reductions in the number of vessels were not considered as the number of trawlers in the area is already low.
Case Study 3: North Sea

Introduction

The North Sea case study deals with complex biological and technical interactions in three different cases focusing on biological interactions and technical interactions in the greater North Sea demersal fisheries and the southern North Sea where fisheries on flatfish and brown shrimps dominate.

Fisheries management based on the MSY concept is a complex task in the North Sea. Multi species simulations show (see biological DST) that the abundance of top predators like cod and saithe determine to a large extent the yield that can be taken from other species leading to the need to trade yield of one country or one fishery against that of another. In a Myfish-NSAC workshop this was identified by stakeholders as being a high potential conflict area and a more pragmatic management concept (Pretty Good Yield) was favoured instead of trying to reach the absolute maximum. In this workshop we also asked eNGOs, fishing industry representatives and politicians what should be the main objectives in future fisheries management for the North Sea. To maximise profit or net present value (MEY) was identified as most suitable objective although social concerns were raised (see technical and southern DSTs). There are trade-offs between economic optimisation and social benefits as employment that have to be taken into account. In this context, mixed fisheries interactions further complicate the situation in the North Sea.

Biological Interaction DST Description

The effect of species interaction in the North Sea on long term yield and sustainability was assessed by producing 100 year forecasts with the stochastic multispecies model (SMS). The model forecasts stock size and catch under the assumption that fish are consumed by fish according to observed stomach contents and a food selection model, assuming constant preferences for prey of a given species and size. Catches of the interacting species cod, saithe, haddock, whiting, herring, sprat, Norway pout and sandeel are described. Cod and saithe are top predators feeding on all other species and, in the case of cod, younger conspecifics. Whiting is a mid-level predator feeding on juvenile cod, haddock and whiting and herring, sprat, Norway pout and sandeel of all ages. Haddock feeds on sandeel and Norway pout only. Herring, sprat, Norway pout and sandeel do not feed on fish in the model.

Three scenarios were examined: maximising the total landings in tonnes; maximising the value of total landings; and an iterative process where it is attempted to get a yield in tonnes close to the maximum of each species while assuring that no species are exploited unsustainably (pretty good yield concept). The probabilities of staying above the biomass reference points Blim (below Blim recruitment gets impaired and the stock is outside safe biological limits) and Bpa (where the uncertainty in the assessments is taken into account to ensure that the stock is above Blim with high probability) were also estimated. In cases where fish eat other fish, the yield in tonnes is generally highest when the predatory fish, which otherwise would eat smaller fish, are fished above the fishing mortality leading to MSY without considering species interactions. This is also the case in the North Sea case study examined here. However, as is seen in single species investigations, substantial changes in fishing mortality around the fishing mortality providing MSY only lead to very minor changes in the yield: yield of predatory fish is only mildly affected by the differences in fishing mortality and hence appear to be virtually identical between scenarios. However, to maximise total landings in kilos or value of the landings, a substantially higher fishing mortality than that leading to single species MSY of cod and saithe is required. This higher fishing mortality requires a higher fishing effort and leads to a cod stock below precautionary limits. In contrast, the scenario leading to all stocks being retained above biological safe biomass limits has a fishing mortality of cod and saithe which are less than that leading to the maximum total landings in the North Sea but above current single species estimates.

Authors: Morten Vinther, Anna Rindorf and Alexander Kempf
### North Sea DST (biological)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Cod</th>
<th>Whiting</th>
<th>Haddock</th>
<th>Saithe</th>
<th>Herring</th>
<th>Industrial (Sandeel, Norway Pout and Sprat)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Sustainable Yield (Weight)</td>
<td>90 kT</td>
<td>40 kT</td>
<td>120 kT</td>
<td></td>
<td>400 kT</td>
<td></td>
</tr>
<tr>
<td>Maximum Sustainable Yield (Euros)</td>
<td>100 kT</td>
<td>40 kT</td>
<td>120 kT</td>
<td></td>
<td>400 kT</td>
<td></td>
</tr>
<tr>
<td>Pretty Good Yield</td>
<td>90 kT</td>
<td>30 kT</td>
<td>30 kT</td>
<td>130 kT</td>
<td>450 kT</td>
<td>840 kT</td>
</tr>
</tbody>
</table>

#### KEY

- = 30 kT
- All Species Above $B_{pa}$
- At Least One Below $B_{pa}$
- At Least One Below $B_{lim}$

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Three scenarios were examined to investigate the effect of fish eating other fish on MSY: maximising the total landings in tonnes; maximising the value of total landings; and an iterative process where it is attempted to get a yield in tonnes close to the maximum of each species while assuring that no species are exploited unsustainably (pretty good yield concept). Yield is indicated by the number of fish of each species. Colour indicates whether the average stock biomass is above the precautionary biomass reference points $B_{pa}$ (black), between $B_{pa}$ and $B_{lim}$ (orange) or below $B_{lim}$ (red).
In the North Sea Mixed Demersal case study, traditional management, given fixed quota shares, has been compared with two MSY scenarios (based on maximising total caught weight and value respectively), and with one MEY scenario, based on maximising the total Net Present Value (discounted profit) for the total fishery over the time period considered (five years). All scenarios assume the landings obligation has been implemented, i.e. all catches are landed and sold. As illustrated in the DST, the comparison revealed that it is more profitable to pursue MEY compared to both traditional management and MSY. The reasons being: (i) traditional management is constrained by being subject to fixed fleet shares of the quotas based on historical landing shares, and (ii) MSY management does not take into account the costs. MEY on the other hand allows flexible fleet quota shares, and reallocates quotas to minimise effort and thus costs. The reduced effort comes at the price of reduced employment. Thus realistic scenarios should lie somewhere in between MSY and MEY acknowledging both the costs of fishing but also the costs of reducing effort and thus employment opportunities.

Authors: Ayoe Hoff, Sophie Smout and Hans Frost

### North Sea DST (technical)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Cod</th>
<th>Whiting</th>
<th>Haddock</th>
<th>Saithe</th>
<th>NPV</th>
<th>Employment</th>
<th>Effort</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional Management</td>
<td>35</td>
<td>20 kt</td>
<td>35 kt</td>
<td>60 kt</td>
<td>€€€€</td>
<td>31 fte</td>
<td>300,000 days</td>
</tr>
<tr>
<td>Maximum Sustainable Yield (Weight)</td>
<td>35</td>
<td>25 kt</td>
<td>40 kt</td>
<td>70 kt</td>
<td>€€€€</td>
<td>50 fte</td>
<td>1,200,000 days</td>
</tr>
<tr>
<td>Maximum Sustainable Yield (Euros)</td>
<td>35</td>
<td>25 kt</td>
<td>40 kt</td>
<td>70 kt</td>
<td>€€€€</td>
<td>54 fte</td>
<td>1,500,000 days</td>
</tr>
<tr>
<td>Maximum Economic Yield (NPV)</td>
<td>35</td>
<td>25 kt</td>
<td>40 kt</td>
<td>60 kt</td>
<td>€€€€€</td>
<td>13 fte</td>
<td>500,000 days</td>
</tr>
</tbody>
</table>

**KEY**

- = 20 kt
- = 5 fte
- = 500 thousand days

All Species Above B
At Least One Species Below B
At Least One Species Below B

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All Species Above B
At Least One Species Below B
At Least One Species Below B
In the southern North Sea case study, we analysed the effects of three different MSY targets (maximising yield in kg, maximising yield in Euro, maximising profit) on i) the ecosystem, ii) the economy of the main fleets (flatfish and brown shrimp fisheries) and iii) their employment. In addition, the constraints imposed by harvesting by-catch like turbot and elasmobranchs in a sustainable way have been investigated (in scenario MEY constrained) and the impact of those constraints has been assessed. The main conclusions from the DST are:

- The current definition of MSY (maximum sustainable yield in kg) is not optimal from an economic and conservation point of view. It leads to a substantial loss in profit and risks the sustainable exploitation of by-catch species.
- Economic efficiency and ecosystem sustainability are not mutually exclusive. Maximising profit leads to a low fishing effort and therefore to a relatively low by-catch and a better size structure in the ecosystem. There is no big loss in profit caused by the protection of by-catch species.

- However, economic optimisation and the protection of by-catch species are achieved with much lower catch and at a high social cost (lower employment).

The spatially explicit bio-economic model Simfish and the ecosystem model Ecopath with Ecosim (EwE) were utilized in parallel. Optimisations were carried out in Simfish and afterwards the optimised fishing effort was transferred to EWE to evaluate the impact on bycatch species and a large fish indicator.

Similarly to the North Sea biological DST for fisheries on North Sea gadoids a compromise has to be found between economic optimisation and social constraints without jeopardising Marine Strategy Framework Directive (MSFD) related targets.

Authors: Morritz Staebler, Alexander Kempf, Jan Jaap Poos, Katell Hamon

### Southern North Sea DST

#### North Sea DST (southern)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Plaice</th>
<th>Sole</th>
<th>Crangon</th>
<th>Employment</th>
<th>Profit (total)</th>
<th>Effort (total)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Maximum Sustainable Yield (Weight)</strong></td>
<td>198 kt</td>
<td>17 kt</td>
<td>50 kt</td>
<td>2350 fte</td>
<td>-2.5 million</td>
<td>81 thousand days</td>
</tr>
<tr>
<td><strong>Maximum Sustainable Yield (Euros)</strong></td>
<td>188 kt</td>
<td>18 kt</td>
<td></td>
<td>2250 fte</td>
<td>27 million</td>
<td>72 thousand days</td>
</tr>
<tr>
<td><strong>Maximum Economic Yield</strong></td>
<td>123 kt</td>
<td>14 kt</td>
<td></td>
<td>450 fte</td>
<td>88 million</td>
<td>34 thousand days</td>
</tr>
<tr>
<td><strong>Maximum Economic Yield (constrained)</strong></td>
<td>131 kt</td>
<td>14 kt</td>
<td></td>
<td>450 fte</td>
<td>87 million</td>
<td>32 thousand days</td>
</tr>
</tbody>
</table>

**KEY**

- Blue fish = All species (Plaice, Sole, Crangon)
- Red fish = All flatfish species
- Green fish = All brown shrimp species
- Yellow fish = All elasmobranch species
- Orange fish = No reference fish category

- Euro = €20 million
- White fish = 50 fte
- White fish = 2350 fte
Case Study 4: Western Waters

Introduction

The Iberian Sea sub case study is focused on the conflicting objectives between artisanal and industrial fleets and on the mixed-fisheries nature of both fleet components. The fishery has been divided in four main fleets, drift netters, purse seiners, trawlers and hookers. In turn their activity has been divided in several metiers. In a mixed-fisheries context and in the framework of the landing obligation policy, the consistency among single stocks TACs is particularly relevant. In that sense, we have compared the performance of the fishery system under actual TAC advice framework, the single stock MSY reference points defined by ICES and a set of reference points calculated simultaneously for all the stocks using a bio-economic optimisation model. In theory, if the overall selection pattern of the whole fishery were constant, the single stock TAC advice derived from the multi-stock reference point would be reached by the fishery simultaneously for all the stocks. On the other hand, when assessing the performance of the fishery system the fleet dynamics is a key element. In order to evaluate the robustness of management strategies to fishermen behaviour we have used two contrasting fleet dynamics, a traditional dynamic and a profit maximisation dynamic. In the scenarios where landings obligation applies, the TAC advice is given in terms of catch instead of landings and all the catches go against the quota share. The undersize individuals, which were discarded in the past count towards the quota but in economic terms they do not contribute to the revenue. The landing obligation has been implemented in the simulations since 2018.

We have used the multi-stock and multi-fleet model FLBEIA to simulate the fishery system from 2013 to 2025. Although the fleets considered catch a large number of stocks only few of them are assessed by ICES. In the model, only the stocks assessed by ICES have been considered explicitly, Hake, monkfish, megrims (whiffagonis and four spot), blue whiting, horse mackerel (south and western) and mackerel. The rest of the stocks caught have been introduced in an aggregated way because enough data to condition them was not available.

Authors: Dorleta Garcia and Raul Prellezo
Case Study 4: Western Waters

DST Description

In the DST the performance of the system is compared using a set of indicators that measure the biologic, economic and social status of the system. The value of all the indicators corresponds with the state of the system in the last year of simulation (2025). The indicators are grouped in three categories, overall level, stock level and fleet level.

Using current reference points the system is biologically sustainable for all the stocks, independently of the fleet dynamics used. However there is high probability of falling below Btrigger when multi-stock reference points are used. The economic performance of the fleet is very different using traditional or profit maximisation fleet dynamics. Both approaches represent extreme plausible options for the dynamic of the fleet and presumably the true dynamics will be somewhere between both. The difference is especially significant in the case of drift netters for which the economic result is threefold using profit maximisation dynamics. The effort exerted, and hence the employment, is also higher in the case of profit maximisation dynamics. The multi-stock reference point combined with landing obligation results in higher profits without compromising the sustainability of the stocks. That is, the impact of landing obligation in the fleets can be overcome using an integrated approach to generate TAC advice. In general the increment in profits is derived from the catch of ‘other’ stock. This stock is an artificial stock with fixed quota and biomass. As its productivity is constant the income derived from its catch is directly related with the amount of effort exerted. In this type of highly mixed fisheries the quota of the stocks subject to the TAC and quota system is not only important by itself but because they allow fishing other valuable stocks not subject to the system. This will become especially important under landing obligation when over-quota discards will be forbidden.

<table>
<thead>
<tr>
<th>Options</th>
<th>Foule Single Stock</th>
<th>Foule Multi Stock Landing Obligation</th>
<th>Max Profit Single Stock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fleet dynamics</td>
<td>Traditional MSY</td>
<td>Traditional MSNSY</td>
<td>Optimise profits MSY</td>
</tr>
<tr>
<td>HCR</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Landing obligation</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Constant effort in Artisnal Fleets</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Capital dynamics</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Biological max ($\text{S150}\times\text{Sp})$</td>
<td>All species</td>
<td>All species</td>
<td>S. Horse Mackereel</td>
</tr>
<tr>
<td>Economic: min (NPV) (million €)</td>
<td>80</td>
<td>100</td>
<td>220</td>
</tr>
<tr>
<td>Economic: % Change in total catch from 2013 to 2025</td>
<td>91%</td>
<td>-103%</td>
<td>119%</td>
</tr>
<tr>
<td>Social: % Change in number of vessels from 2013 to 2025</td>
<td>-23%</td>
<td>-16%</td>
<td>-12%</td>
</tr>
<tr>
<td>Ecological: % Change in discards to landings ratio from 2013 to 2025</td>
<td>-55%</td>
<td>-43%</td>
<td>-31%</td>
</tr>
<tr>
<td>Fish landings (tonnes)</td>
<td>9,000</td>
<td>10,500</td>
<td>8,000</td>
</tr>
<tr>
<td>------------------------</td>
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<td>-------</td>
</tr>
<tr>
<td>Horse Mackerel landings - North (tonnes)</td>
<td>27,500</td>
<td>28,500</td>
<td>29,500</td>
</tr>
<tr>
<td>Horse Mackerel landings - North (tonnes)</td>
<td>14,500</td>
<td>15,500</td>
<td>18,500</td>
</tr>
<tr>
<td>4-spot Megrim landings (tonnes)</td>
<td>1,400</td>
<td>750</td>
<td>1,200</td>
</tr>
<tr>
<td>Mackerel landings (tonnes)</td>
<td>11,800</td>
<td>11,000</td>
<td>11,800</td>
</tr>
<tr>
<td>Megrim landings (tonnes)</td>
<td>540</td>
<td>540</td>
<td>660</td>
</tr>
<tr>
<td>Monkfish landings (tonnes)</td>
<td>1,200</td>
<td>1,250</td>
<td>1,500</td>
</tr>
<tr>
<td>Blue Whiting landings (tonnes)</td>
<td>2,750</td>
<td>2,750</td>
<td>2,700</td>
</tr>
<tr>
<td>Other (tonnes)</td>
<td>72,500</td>
<td>81,500</td>
<td>121,500</td>
</tr>
<tr>
<td>Spanish Trawler - NPV (€ 100's millions)</td>
<td>3.6</td>
<td>4.1</td>
<td>4.8</td>
</tr>
<tr>
<td>Spanish Trawler - Effort (thousands of days)</td>
<td>23</td>
<td>17</td>
<td>28</td>
</tr>
<tr>
<td>Spanish Drift and/or Fixed Netters - NPV (€ 100's millions)</td>
<td>1</td>
<td>1.3</td>
<td>3</td>
</tr>
<tr>
<td>Spanish Drift and/or Fixed Netters - Effort (thousands of days)</td>
<td>34</td>
<td>47</td>
<td>118</td>
</tr>
<tr>
<td>Spanish vessels using hooks - NPV (€ 100's millions)</td>
<td>0.8</td>
<td>1</td>
<td>2.2</td>
</tr>
<tr>
<td>Spanish vessels using hooks - Effort (thousands of days)</td>
<td>10</td>
<td>14</td>
<td>89</td>
</tr>
</tbody>
</table>
Case Study 5: Widely Ranging Fish

The Indian Ocean is an area of great commercial interest for European fishing industries. Among others, European fleets target bigeye, yellowfin and skipjack, three tuna species that form the tropical tuna fisheries in the Indian Ocean. In this DST we illustrate the consequences of management of these tuna species under the MSY framework aiming for high and stable yields, which was indicated to be the preferred outcome of fisheries management by stakeholders. We combined hypotheses on the fish stocks’ interactions with the Southern Oceanic Index (SOI), and investigated the possibility of a management system, based on the overall productivity of large pelagic fisheries: Tropical tuna fisheries appear to operate in a single species environment, but in fact make decisions in a multispecies context. In the case of tropical tuna, this is a salient aspect due to the compensatory influence of the SOI on the main three species considered (bigeye, yellowfin and skipjack tunas). In the DST, we compare the effect of reducing fishing mortality in a single species and multispecies environment. Taking multi-species considerations into account makes a substantial difference in the perception of stock management. The ability to manage the stocks with low TAC variability for bigeye (higher Inter Annual Variation (IAV)) and yellowfin (lower IAV) is markedly different. The catches are similar under both scenarios for bigeye and skipjack but markedly lower for yellowfin under the multi-species scenario. Overall, the probability to meet conservation objectives is higher under the multi-species scenario at values close to FMSY than under the single species scenario where, on average, species must be fished 25% or more below FMSY to meet these conservation objectives. The main driver behind the differences is the climatic influence on the different stocks. This necessity to incorporate multispecies consideration is highlighted by the results on yellowfin which differ most in yield and stability in yield between the two scenarios. If management were to pursue single-species management, there is a high risk of overexploitation of yellowfin at or below FMSY. If multispecies targets would be implemented however, the risk is substantially lower, and will result in sustainable and precautionary management at values just below FMSY but a considerable loss of production potential.

Author: Hilario Murua
### DST on tunas in the Indian Ocean

#### Single-species management DST

<table>
<thead>
<tr>
<th>Fishing mortality</th>
<th>Bigeye</th>
<th>Yellowfin</th>
<th>Skipjack</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00 *F&lt;sub&gt;MSY&lt;/sub&gt;</td>
<td><img src="image1" alt="Graph" /></td>
<td><img src="image2" alt="Graph" /></td>
<td><img src="image3" alt="Graph" /></td>
</tr>
<tr>
<td></td>
<td>6%</td>
<td>93%</td>
<td>25%</td>
</tr>
<tr>
<td>0.91 *F&lt;sub&gt;MSY&lt;/sub&gt;</td>
<td><img src="image4" alt="Graph" /></td>
<td><img src="image5" alt="Graph" /></td>
<td><img src="image6" alt="Graph" /></td>
</tr>
<tr>
<td></td>
<td>4%</td>
<td>96%</td>
<td>21%</td>
</tr>
<tr>
<td>0.83 *F&lt;sub&gt;MSY&lt;/sub&gt;</td>
<td><img src="image7" alt="Graph" /></td>
<td><img src="image8" alt="Graph" /></td>
<td><img src="image9" alt="Graph" /></td>
</tr>
<tr>
<td></td>
<td>4%</td>
<td>86%</td>
<td>18%</td>
</tr>
<tr>
<td>0.77 *F&lt;sub&gt;MSY&lt;/sub&gt;</td>
<td><img src="image10" alt="Graph" /></td>
<td><img src="image11" alt="Graph" /></td>
<td><img src="image12" alt="Graph" /></td>
</tr>
<tr>
<td></td>
<td>3%</td>
<td>54%</td>
<td>16%</td>
</tr>
<tr>
<td>0.71 *F&lt;sub&gt;MSY&lt;/sub&gt;</td>
<td><img src="image13" alt="Graph" /></td>
<td><img src="image14" alt="Graph" /></td>
<td><img src="image15" alt="Graph" /></td>
</tr>
<tr>
<td></td>
<td>3%</td>
<td>26%</td>
<td>14%</td>
</tr>
<tr>
<td>0.67 *F&lt;sub&gt;MSY&lt;/sub&gt;</td>
<td><img src="image16" alt="Graph" /></td>
<td><img src="image17" alt="Graph" /></td>
<td><img src="image18" alt="Graph" /></td>
</tr>
<tr>
<td></td>
<td>3%</td>
<td>16%</td>
<td>13%</td>
</tr>
</tbody>
</table>

#### KEY

- `>` = 50,000 tonnes
- `~` = 75% average annual change in TAC (AV)
- `*` = Probability of meeting conservation objectives
  - 0-25% 25-50%
  - 50-75% 75-100%
- Relative changes in TAC
  - x% = average annual change in TAC (AV)
## Multi-species management DST

<table>
<thead>
<tr>
<th>Fishing mortality</th>
<th>Bigeye</th>
<th>Yellowfin</th>
<th>Skipjack</th>
</tr>
</thead>
<tbody>
<tr>
<td>( F_{\text{MSY}} )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.00</td>
<td>32%</td>
<td>4%</td>
<td>22%</td>
</tr>
<tr>
<td>0.91</td>
<td>31%</td>
<td>3%</td>
<td>21%</td>
</tr>
<tr>
<td>0.83</td>
<td>30%</td>
<td>3%</td>
<td>20%</td>
</tr>
<tr>
<td>0.77</td>
<td>28%</td>
<td>3%</td>
<td>19%</td>
</tr>
<tr>
<td>0.71</td>
<td>27%</td>
<td>3%</td>
<td>18%</td>
</tr>
<tr>
<td>0.67</td>
<td>25%</td>
<td>2%</td>
<td>17%</td>
</tr>
</tbody>
</table>

### KEY

- \( \text{Fishing mortality} = 50,000 \text{ tonnes} \)
- \( \text{Probability of meeting conservation objectives} \)
  - 0-25% 25-50%
  - 50-75% 75-100%
- \( \text{Relative annual changes in TAC} \)
- \( \text{\% average annual change in TAC (TAC)} \)
The complexity in the advice and management of herring and sprat in areas IV and IIIa is caused by the overlap between stocks, area and fisheries: two overlapping herring stocks (North Sea autumn spawning (NSAS) herring and western Baltic spring spawning (WBSS) herring), five fleets (three for human consumption and two for industrial use), TACs by area and scientific advice by stock, etc. In addition, there are further ramifications because different member states hold different TAC shares for the different areas. This DST visualises the trade-offs in close collaboration with relevant stakeholders in the Pelagic Advisory Council.

Under the current management regime (i.e. WKHERTAC), the TAC splitting is done according to the management plans for North Sea herring, the management strategy for WBSS herring and the Bescapement strategy for North Sea sprat. Five management scenarios have been evaluated representing five different ways of splitting the TACs for the three fish stocks (North Sea herring, North Sea sprat, western Baltic herring):

**Biological:** make calculations as close as possible to following Fmsy advice per fish stock

**Simple:** make “back of an envelope” calculation of possible TACs

**HERTAC:** account for all political agreements currently in place

**Industrial:** double the F in industrial fisheries.

**Landing obligation:** Transfer 9% of the sprat TAC to North Sea herring outtake.

Authors: Niels Hintzen, Martin Pastoors, Claus Reedz Sparrevohn, Lotte Worsoe Clausen, Christine Röckmann, Mikael von Deurs

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### Multi-species management DST

<table>
<thead>
<tr>
<th>Scenario</th>
<th>North Sea Herring</th>
<th>West Baltic Herring</th>
<th>North Sea Sprat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yield A</td>
<td>Yield B</td>
<td>IAV</td>
</tr>
<tr>
<td>Biological</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biological</td>
<td>350 kT</td>
<td>16 kT</td>
<td>13%</td>
</tr>
<tr>
<td>Simple</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simple</td>
<td>360 kT</td>
<td>9.8 kT</td>
<td>12%</td>
</tr>
<tr>
<td>WKHERTAC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WKHERTAC</td>
<td>320 kT</td>
<td>12 kT</td>
<td>16%</td>
</tr>
<tr>
<td>Industrial</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industrial</td>
<td>310 kT</td>
<td>15 kT</td>
<td>16%</td>
</tr>
<tr>
<td>Landing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landing</td>
<td>330 kT</td>
<td>11 kT</td>
<td>16%</td>
</tr>
</tbody>
</table>

**KEY**

- = 100 kT
- = 5 kT tonnes
- = 5% average annual change in TAC (IAV)
- = 5% risk of falling below blim
- = 5% risk of falling below blim
### Model Surveys

The surveys were undertaken in order to communicate uncertainty that is associated with model based results. Four sources of uncertainty are presented following questionnaire-based interviews with individual modellers. Subjective judgements were elicited about the quality of data and knowledge of processes that went into building models. These judgements were scored according to the template developed for such purposes in the Jakfish project. The template is reproduced in this newsletter. Two other sections were added: one about the ways in which the model has been tested and validated and another regarding specific sources of uncertainty and robustness which were examined.

Authors: Adrian Leach, Polina Levontin, Paul Baranowski and John Mumford.

<table>
<thead>
<tr>
<th>Survey</th>
<th>Ad hoc coverage in time and space</th>
<th>Partly covered</th>
<th>Good coverage and good sampling scheme</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recruitment observations</td>
<td>Partly covered but disagreements between scientists and fisher- men about status</td>
<td>Partly covered by survey but the picture coincides roughly with fisher- men's observations</td>
<td>Good survey coverage. In agreement with fishermen</td>
</tr>
<tr>
<td>Catch data</td>
<td>Compliance problems or serious sampling problems</td>
<td>Compliance estimates included, and sampling scheme with some good coverage but some gaps as well</td>
<td>Full compliance and sufficient sampling schemes</td>
</tr>
<tr>
<td>Selectivity</td>
<td>Fairly well sampled, but not predictable</td>
<td>Fairly well sampled. Predictable due to stable fleet and gear situation</td>
<td></td>
</tr>
<tr>
<td>Bycatch</td>
<td>Some technical regulations, but a problem</td>
<td>All Bycatch counted against the quota</td>
<td>Very low bycatch</td>
</tr>
</tbody>
</table>

### Key: Knowledge Scores

<table>
<thead>
<tr>
<th>Stock recruitment</th>
<th>Unknown</th>
<th>No clear relationship, recent average used</th>
<th>Possible relationship</th>
<th>Clear visual and functional relationship</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growth</td>
<td>Unknown</td>
<td>Poor sampling, and environmental effects on growth poorly understood</td>
<td>Well sampled, but causes of fluctuations poorly understood</td>
<td>Well sampled and causes of fluctuations are well understood</td>
</tr>
<tr>
<td>Natural Mortality</td>
<td>Unknown predation by cod and other top predators of the ecosystem</td>
<td>Poor estimates of M.</td>
<td>Reliable estimates of M, but not at early life stages</td>
<td>Reliable estimates of M</td>
</tr>
<tr>
<td>State of stock(s)</td>
<td>Inadequate data and knowledge in assessment</td>
<td>Rather low quality assessment</td>
<td>High quality assessment, but limited focus on uncertainty estimates</td>
<td>High quality assessment with uncertainty estimates</td>
</tr>
<tr>
<td>Impact of Climate Change</td>
<td>No knowledge of temperature effects on stock</td>
<td>Limited knowledge, and not accounted for in modelling</td>
<td>Known impact on growth or recruitment or distribution</td>
<td>Well understood consequences of experienced temperature fluctuations</td>
</tr>
<tr>
<td>Stock interactions</td>
<td>Unknown and not addressed</td>
<td>Mixing, and not addressed adequately</td>
<td>Mixing occurs but is sampled and monitored</td>
<td>No mixing, not a problem</td>
</tr>
<tr>
<td>Spatial aspects</td>
<td>Unknown whether separate components exist</td>
<td>Not accounted for. Limited knowledge on how to separate components</td>
<td>Partly accounted through spatial and fleet-based data</td>
<td>Fully accounted for</td>
</tr>
<tr>
<td>Implementation</td>
<td>Advice not followed and limited control</td>
<td>Limited control</td>
<td>Advice usually followed. Control increases compliance</td>
<td>Advice followed and adequate catch control</td>
</tr>
</tbody>
</table>
## Models

<table>
<thead>
<tr>
<th></th>
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</tr>
</tbody>
</table>

### Data
- Survey data
- Recruitment observation
- Catch data
- Selectivity
- Bycatch
- Stock recruitment
- Growth
- Natural mortality
- State of stock(s)
- Impact of Climate Change
- Stock interactions
- Spatial aspects
- Implementation of management decisions

### Knowledge
- Selectivity
- Natural mortality
- State of stock(s)
- Stock interactions
- Spatial aspects
- Implementation of management decisions

### Model tests
- Used alternative stock assessments
- Performed MCMC
- Sensitivity to small param. changes
- Performed MSE
- Validated with data not used in the model
- Natural mortality
- Selectivity
- Migration
- Stock recruitment
- Assumption about unfished stock size
- Growth
- Prices and costs
- Effects of Climate Change
- Other environmentally forced regime shifts
- Standardization of catch statistics
- Underreporting

This project has received funding from the European Union’s Seventh Framework Programme for research, technological development and demonstration under grant agreement no 289257.