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Support to a robust model assessment, benchmark and development of a management strategy evaluation for cod in NAFO Division 3M

European Maritime and Fisheries Fund (EMFF)

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FRAMEWORK CONTRACT
EASME/EMFF/2016/008

Provision of Scientific Advice for Fisheries Beyond EU Waters

Support to a robust model assessment, benchmark and development of a management strategy evaluation for cod in NAFO Division 3M

Final Report

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1.2. Acronyms

3Y: 3 Years Mean Operating Model.

ALKs: Age length keys.

B_{lim}: Limit reference point for spawning stock biomass.

CEFAS: Centre for Environment, Fisheries and Aquaculture Science.

CV: Coefficient of variation

DD: Density-Dependent Operating Model.

DG MARE: Directorate-General for Maritime Affairs and Fisheries.

Div.: NAFO Division.

EASME: Executive Agency for Small and Medium-sized Enterprises.

EU: European Union.

F: Fishing mortality.

$F_{30\%SPR}$: Fishing mortality that reduces the 70% of the spawning stock biomass per recruit relative to the unfished level.

FC: NAFO Fisheries Commission. Currently, known as Commission (Comm).

F_{lim}: Limit reference point for fishing mortality.

F_{MSY}: Fishing mortality that gives the Maximum Sustainable Yield in the long term.

GADGET: Globally applicable Area-Disaggregated General Ecosystem Toolbox.

HCR: Harvest Control Rule.

ICES: International Council for the Exploration of the Sea.

IEO: Instituto Español de Oceanografía.

IIM: Instituto de Investigaciones Marinas.

IMARES: Institute for Marine Resources and Ecosystem Studies. Currently, known as Wageningen Marine Research (WUR).

IPMA: Instituto Português do Mar e da Atmosfera.

IRD: L'Institut de Recherche pour le Développement.

M: Natural mortality.

MFS: Model-Free Slope HCR.

MFT: Model-Free Target HCR.

MG: M from the GADGET Operating Model.

MO: Management Objective.

MRAG: Marine Resources Assessment Group.

MS: M by steps Operating Model.

MSE: Management Strategy Evaluation.

MSY: Maximum Sustainable Yield.

MV: M as vector Operating Model.

NAFO: Northwest Atlantic Fisheries Organization.

OM: MSE Operating Model.

PA: NAFO Precautionary Approach.

PAF: NAFO Precautionary Approach Framework.

PS: MSE performance statistics.

q: Survey catchability.

RW: Random Walk Operating Model.

SAM: State Space assessment model.

SC: NAFO Scientific Council.

SC03: Specific Contract (SC) Nº 3. FRAMEWORK CONTRACT–EASME/EMFF/2016/008-Provision of scientific advice for fisheries beyond EU waters. Support to a robust model assessment, benchmark and development of a management strategy evaluation for cod in NAFO Division 3M.

SCAA: Statistical catch-at-age analysis.

SCR: NAFO Scientific Council Research Document.

SCS: NAFO Scientific Council Summary Document.

SoP: Sum of Products.

SSB: Spawning Stock Biomass.

TAC: Total allowable catch.

WG-RBMS: NAFO Working Group on Risk Based Management Strategies.

XSA: eXtended Survivor Analysis.

1 EXECUTIVE SUMMARY

Purpose of the specific contract

The purpose of this specific study is to provide the Directorate-General for Maritime Affairs and Fisheries (DG MARE) and the Northwest Atlantic Fisheries Organization (NAFO) Scientific Council with technical and scientific analysis to:

- Address the shortcomings of the current assessment model, identified by the NAFO Working Group on Risk Based Management Strategies (WG-RBMS) (NAFO FC/SC 15/02), the Scientific Council (SC) (NAFO SCS 15/12) and the Fisheries Commission (FC) (NAFO/FC 15/23) in 2015.
- Support the development of the 3M cod benchmark process within NAFO.
- Develop and test the robustness of various Harvest Control Rules (HCR) for cod in Div. 3M to achieve the management objectives to be established by the FC.

To achieve these objectives, three different Tasks were designed:

<u>Task 1.</u> Organise a workshop focusing on the current assessment model and the uncertainty in the projections for cod in Division 3M.

<u>Task 2.</u> Support the development of the benchmark assessment for cod in Div. 3M.

<u>Task 3.</u> Support the development of the multiannual management plan for cod in Div. 3M.

The aim of this Executive Summary is to present the main results of each Project Task and the conclusions and decisions about the 3M cod Management Strategy Evaluation (MSE) made by the NAFO SC and the NAFO WG-RBMS, based on these results.

Main results of the Tasks

<u>Task 1:</u> Organise a workshop focusing on the 2015 assessment model and the uncertainty in the projections for cod in Division 3M to address the shortcomings identified by the NAFO Working Group on Risk Based Management Strategies (WG-RBMS), the Scientific Council and the Fisheries Commission in 2015.

The workshop was held in Vigo during March 21st – 23rd 2017. The results of this Task have been detailed in the workshop Report sent to the EASME on May 9th 2017 (Deliverable D1.1.).

The main results of the workshop were proposals submitted to the June 2017 SC meeting and recommendations to the benchmark process. All the proposals and recommendations were endorsed by the SC.

Proposals submitted to the June 2017 SC meeting.

1. The workshop **proposed** that the next assessment uses the final year values of the inputs in the projections instead of the usual mean of the final three years, to reduce the impact of

the trend in biological parameters. It also recommended that accounting for uncertainty must be studied in more depth before considering its implementation.

Conclusions of the June 2017 SC meeting: It was agreed to use in the projections the final year values at age for the biological parameters due to the marked decreasing trend shown for these parameters, and to use the last three years' mean for the selectivity, because the selectivity at age has varied without trend in recent years.

2. The workshop **proposed** a new method to estimate risk in the 3M cod projections. The new method solves the problems raised by the FC in 2015 by measuring the risk associated with fishing a unique TAC, instead of measuring the risk associated with a distribution of TACs as done in the past. The workshop found this procedure more reasonable since management is done based on a single deterministic TAC value (the median of the distribution of the TACs).

   Conclusions of the June 2017 SC meeting: The SC agreed to use the new projections method and risk measure proposed in the workshop for all stocks that use an assessment that incorporates uncertainty.

These two proposals approved by the SC solved the main shortcomings identified by the WG-RBMS, the SC and the FC in 2015.

Recommendations for the 2018 benchmark process. Apart from the proposals, the workshop made a series of technical recommendations about the biological parameters, the reference points, the assessment model and the catchability to discuss in the benchmark process of the following year.

Conclusions of the June 2017 SC meeting: The SC endorsed all the workshop recommendations for the 3M cod 2018 benchmark.

Task 2: Support the development of the benchmark assessment for cod in Div. 3M.

One of the objectives of this Task was to organize a **workshop to solve the age reading problems**. This workshop was held in Vigo during November 8th- 9th 2018. The results of this workshop have been detailed in a report sent to EASME on February 6th 2018 (Deliverable D2.1).

The workshop showed significant progress in the correspondence between readers, especially when only clear-pattern otoliths and the most experienced readers are compared. The workshop concluded that the interpretation of the age readings is significantly different only when the otoliths with unclear-pattern are used. These differences were well identified and seem to be occasional in some years. Some recommendations for future work to solve these problems were made. Meanwhile, it was recommended that the application of the survey ALKs to commercial length distributions in the assessment of the 3M cod continues.

An SC meeting via WebEx took place on March 13th 2018 in order to review the available data and there it was decided the best 3M cod data to be used in future 3M cod analyses. The time series of both commercial and survey data were reviewed. The main results of this meeting were the decision to shorten the assessment period, and thus to only include data from 1988 onwards, and correct some errors in the data used in previous assessments. The decision to shorten the assessment period was taken because there were few data prior to 1988 and their quality was not good.

The **benchmark meeting** was held in Lisbon (Portugal) in April 9th- 13th 2018. Three external experts invited by NAFO (Carmen Fernández, Jim Ianelli and Mike Palmer) attended the meeting. The results of this meeting have been detailed in the report sent to EASME on May 9th 2018 (Deliverable D2.2). The main SC conclusions, after analysing all SC03 work documents, were:

Assessment models

Four different assessment models were presented during the benchmark meeting: Bayesian XSA, Bayesian SCAA, SAM and GADGET. Several scenarios exploring different model configurations were run.

The final runs of the Bayesian XSA and SCAA showed better fits to the survey data and results of the two models were similar to each other. The greater flexibility of the SCAA was considered by the SC to be an advantage over the XSA, making it a more powerful assessment tool, and it was recommended as the basis of the June 2018 assessment for this stock.

Model parameters

- M value: The final conclusion of the benchmark meeting was to use a vector of M (variable by age and constant for all years) as prior in the Bayesian models, with a CV of 15%.
- Maturity ogives: the benchmark meeting decided to use in the assessment the maturity ogives derived from the EU survey data.
- Priors of the current assessment: the values of the prior distributions for the recruitment and initial abundance at age for the proposed new assessment model (SCAA) were decided. It was also decided to fix the variability of the survey catchability since its estimate in the model was very poor.
- Survey catchability depending on abundance: based on the results of the different models, it was decided to use abundance-dependent catchability for age 1 only.

Review of the Limit Reference Points

- B_{lim}: Estimate a new B_{lim} during the June 2018 SC meeting based on the results of the assessment approved during this meeting following the NAFO Precautionary Approach (PA) guidelines.

- F_{lim}: Estimate a new F_{lim} during the June 2018 SC meeting based on the results of the assessment approved during this meeting following the NAFO PA guidelines.

  The approved assessment results were used to estimate the limit reference points during the June 2018 SC meeting. SSB = 20 000 t was set as B_{lim}. F_{lim} proxy was estimated based on $F_{30\%SPR}$ calculated with the 2015-2017 data, and its median was 0.153. This period was chosen due to the rapid change in biological parameters in the stock.

The work carried out by the SC03 allowed the SC to change the assessment model to be used in June 2018.

<u>Task 3</u>: Support the development of the multiannual management plan for cod in Div. 3M. Develop and test the robustness of various Harvest Control Rules (HCR) for cod in Div. 3M to achieve the management objectives to be established by the Fisheries Commission.

The objectives, priorities and guidelines of this Task were closely related to the work of the SC and the Joint FC-SC WG-RBMS in 2018 and 2019. Most of the decisions on the 3M cod MSE that these NAFO Groups have made were based on the results presented by the SC03. Detailed information on the two 2018 Working Groups was presented in Deliverable D3.1 (September 2018) and detailed information on the two 2019 Working Groups was presented in deliverable D3.2 (May 2019).

The June 2018 SC agreed:

- The data to be used in the MSE and the guidelines to develop the OMs to be tested.
- The base case reference OM: set as the model assessment approved in 2018.
- Simulation period: a 20- year period was decided for carrying out the simulations.
- Harvest Control Rules (HCR) guidelines: It was recommended to apply the same guidelines for 3M cod as the ones used during the 2+3KLMNO Greenland halibut MSE process, including a Model-Free HCR.

The September 2018 WG-RBMS agreed:

- The 3M cod MSE calendar: starting in fall 2018 and ending in September 2019, prior to the September 2019 NAFO Annual Meeting.
- The general guidelines for the work of SC03: development of OMs and projection specifications, HCRs to be tested and proposal of a complete set of management objectives (MO), performance statistics (PS) and risks.

Two external experts invited by NAFO (Jim Ianelli and Daniel Howell) attended the January 2019 SC extraordinary meeting. This meeting analysed the intersessional work carried out by the SC03 and decided:

- The methods to estimate the different components of the initial set of OMs: Natural Mortality, survey catchability, biological parameters, selectivity, stock recruit relationship and the generation of "observed" indices in projections.
- Agreements on reference points:
    - Reference points to be estimated for each OM and iteration.
    - $F_{30\%SPR}$ computed dynamically within the projections going forward (using, in each year, the average of the three most recent years) to be used as a proxy for $F_{MSY}=F_{lim}$.
    - It was agreed that SSB_{2007} would be used as B_{lim}.
- Candidate HCRs to be tested: Model-Free Slope (MFS), Model-Free Target (MFT), F=0 and trigger/20%, i.e. a constant harvest rate of 20%, or some other value, which is reduced gradually when the stock biomass index falls below a trigger value (as a possibility if time permits).
- First proposals for full set of Management Objectives (MO)/Performances Statistics (PS)/Risks.

- The SC identified 28 priority scenarios to be presented at the April 2019 WG-RBMS meeting.

The April 2019 WG-RBMS meeting analysed the results of the priority scenarios agreed by the January 2019 SC extraordinary meeting and concluded:

- That considering the performance of the initial set of MSE, it was unlikely that the MSE would produce any results that satisfy the draft performance criteria. Therefore, it was agreed to focus the efforts on giving advice during the June 2019 SC meeting based on an assessment model instead of further developing the MSE.
- The Technical Team (SC03) will continue to develop the Density-Dependent (DD) model and the low recruitment scenarios for September 2019.
- WG-RBMS should meet prior to the 2019 NAFO Annual meeting to consider how to proceed, including a revised timeline if the decision is to continue.

The September 2019 WG-RBMS meeting analysed the final results of the scenarios agreed by the January 2019 SC meeting and concluded:

- That work in WG-RBMS on the 3M cod MSE should be suspended for the time being. This conclusion was reached based on the strong variability observed in the stock dynamics and biological parameters in the past, that create substantial difficulties for developing realistic future simulations and successful development of an HCR. The WG-RBMS would reopen the issue when SC determines that conditions are such that there is a reasonable probability of success.
- WG-RBMS highlights the enormous amount of hard work that has gone into this process, particularly from the Technical Team (SC03), whose efforts and good quality of work were gratefully acknowledged. Even though this work has not resulted in immediate success, a lot knowledge and expertise has been gained, which will be an asset to any future MSE process.
- Concerning future MSE processes, WG-RBMS noted that significant challenges were encountered in meeting the timetable set for the MSE processes for both 3M cod and 2+3KLMNO Greenland halibut. WG-RBMS recommends that timeframes set for future MSE processes should be realistic, taking full account of the very large amount of work required. Sufficient time and human capacity should be allowed for the development of the technical work, review, communication with relevant actors and reporting of results.

2 RESUMEN EJECUTIVO

Propósito del contrato específico

El propósito de este estudio específico es proporcionar análisis técnicos y científicos a la Dirección General de Asuntos Marítimos y Pesca (DG MARE) y al Consejo Científico de la Organización de Pesquerías del Atlántico Noroeste (NAFO) para:

- Abordar las deficiencias del actual modelo de evaluación, identificadas por el Grupo de Trabajo de la NAFO sobre Estrategias de Gestión Basadas en el Riesgo (WG-RBMS) (NAFO FC/SC 15/02), el Consejo Científico (CC) (NAFO SCS 15/12) y la Comisión de Pesca (FC) (NAFO/FC 15/23) en 2015.
- Apoyar el desarrollo del proceso de benchmark del bacalao de la 3M dentro de la NAFO.
- Desarrollar y poner a prueba la solidez de varias Normas de Control de la Captura (HCR) del bacalao en la División 3M para lograr los objetivos de gestión que establezca la Comisión de Pesca.

Para lograr estos objetivos, se diseñaron tres tareas diferentes:

Tarea 1. Organizar un taller centrado en el modelo de evaluación actual y en la incertidumbre de las proyecciones para el bacalao en la División 3M.

Tarea 2. Apoyar el desarrollo de la evaluación de benchmark para el bacalao en la División 3M.

Tarea 3. Apoyar el desarrollo del plan de gestión plurianual para el bacalao en la División 3M.

El objetivo de este Resumen Ejecutivo es presentar los principales resultados de cada Tarea de Proyecto y las conclusiones y decisiones sobre la Evaluación de la Estrategia de Gestión del Bacalao (MSE) de la División 3M realizadas por el CC y el GT-RBMS de la NAFO, basadas en estos resultados.

Principales resultados de las tareas

Tarea 1: Organizar un taller centrado en el modelo de evaluación de 2015 y la incertidumbre en las proyecciones para el bacalao en la División 3M para abordar las deficiencias identificadas por el Grupo de Trabajo de la NAFO sobre estrategias de gestión basadas en el riesgo (WG- RBMS), el Consejo Científico (CC) y la Comisión de Pesca (CP) en 2015.

El taller se celebró en Vigo del 21 al 23 de marzo de 2017. Los resultados de esta Tarea se han detallado en el Informe del taller enviado a la EASME el 9 de mayo de 2017 (Entregable D1.1.).

Los principales resultados del taller fueron las propuestas presentadas en la reunión del CC de junio de 2017 y las recomendaciones para el proceso de benchmarking. Todas las propuestas y recomendaciones fueron aprobadas por el CC.

Propuestas presentadas en la reunión del Comité Científico de junio de 2017.

1. En el taller se propuso que en la próxima evaluación se utilizaran los valores del último año de los inputs de las proyecciones en lugar de la habitual media de los tres últimos años, para reducir el impacto de la tendencia de los parámetros biológicos. También recomendó que se contabilizara más a fondo la incertidumbre antes de considerar su aplicación.

Conclusiones de la reunión del Comité Científico de junio de 2017: Se acordó utilizar en las proyecciones los valores del último año de edad para los parámetros biológicos debido a la marcada tendencia decreciente mostrada por estos parámetros, y utilizar la media de los tres últimos años para la selectividad, ya que la selectividad en la edad ha variado sin tendencia en los últimos años.

2. El taller propuso un nuevo método para estimar el riesgo en las proyecciones del bacalao 3M. El nuevo método resuelve los problemas planteados por la Comisión de Pesca en 2015 al medir el riesgo asociado a la pesca de un TAC único, en lugar de medir el riesgo asociado a una distribución de los TAC como se hacía en el pasado. El taller consideró que este procedimiento era más razonable, ya que la ordenación se realiza sobre la base de un único valor de TAC determinante (la mediana de la distribución de las TAC).

Conclusiones de la reunión del CC de junio de 2017: El CC convino en utilizar el nuevo método de proyecciones y la medida de riesgo propuestos en el taller para todas las poblaciones que utilizan una evaluación que incorpora la incertidumbre.

Estas dos propuestas aprobadas por el CC resolvieron las principales deficiencias identificadas por el GT-RBMS, el Consejo Científico y el Comité de Pesca en 2015.

Recomendaciones para el proceso de evaluación comparativa de 2018. Además de las propuestas, el taller formuló una serie de recomendaciones técnicas sobre los parámetros biológicos, los puntos de referencia, el modelo de evaluación y la capturabilidad para ser discutidas en el proceso de puntos de referencia del año siguiente.

Conclusiones de la reunión del Consejo Científico de junio de 2017: El CC aprobó todas las recomendaciones del tallerbenchmark de bacalao 3M 2018.

Tarea 2: Apoyar el desarrollo de la evaluación benchmark para el bacalao en la Div. 3M.

Uno de los objetivos de esta tarea era organizar un taller para resolver los problemas de lectura de la edad. Este taller se celebró en Vigo durante los días 8 y 9 de noviembre

de 2018. Los resultados de este taller se han detallado en un informe enviado a EASME el 6 de febrero de 2018 (Entregable D2.1).

El taller mostró un progreso significativo en la correspondencia entre los lectores, especialmente cuando sólo se comparan otolitos de patrones claros y los lectores más experimentados. El taller concluyó que la interpretación de las lecturas de la edad sólo es significativamente diferente cuando se utilizan otolitos con patrones poco claros. Estas diferencias se identificaron bien y parecen ser ocasionales en algunos años. Se formularon algunas recomendaciones para resolver estos problemas en futuros trabajos. Mientras tanto, se recomendó que se siguieran aplicando las claves edad-longitud de las campañas a las distribuciones de longitudes de pesca comercial en la evaluación del bacalao 3M.

El 13 de marzo de 2018 se celebró una reunión del Consejo Científico a través de WebEx para revisar los datos disponibles y allí se decidió que los mejores datos del bacalao 3M se utilizarían en futuros análisis del bacalao 3M. Se revisaron las series temporales de datos comerciales y de campañas. Los principales resultados de esta reunión fueron la decisión de acortar el período de evaluación y, por lo tanto, incluir sólo los datos de 1988 en adelante, y corregir algunos errores en los datos utilizados en evaluaciones anteriores. La decisión de acortar el período de evaluación se adoptó porque había pocos datos antes de 1988 y su calidad no era buena.

La reunión de evaluación benchmark se celebró en Lisboa (Portugal) del 9 al 13 de abril de 2018. Asistieron a la reunión tres expertos externos invitados por la NAFO (Carmen Fernández, Jim Ianelli y Mike Palmer). Los resultados de esta reunión se han detallado en el informe enviado a EASME el 9 de mayo de 2018 (Entregable D2.2). Las principales conclusiones del CC, después de analizar todos los documentos de trabajo del SC03, fueron:

<u>Modelos de evaluación</u>

Durante la reunión de benchmark se presentaron cuatro modelos de evaluación diferentes: Bayesiano XSA, Bayesiano SCAA, SAM y GADGET. Se ejecutaron varios escenarios que exploraban diferentes configuraciones de modelos.

Las ejecuciones finales de la XSA Bayesiana y la SCAA mostraron mejores ajustes a los datos de campañas y los resultados de los dos modelos fueron similares entre sí. El SC consideró que la mayor flexibilidad del SCAA era una ventaja sobre el XSA, lo que lo convierte en una herramienta de evaluación más potente, y se recomendó como base de la evaluación de junio de 2018 para este stock.

<u>Parámetros del modelo</u>

- Valor M: La conclusión final de la reunión de benchmark fue utilizar un vector de M (variable por edad y constante para todos los años) como *a priori* en los modelos bayesianos, con un CV del 15%.
- Ojivas de madurez: la reunión de benchmark decidió utilizar en la evaluación las ojivas de madurez derivadas de los datos de campañas de la UE.

- Valores *a priori* de la evaluación actual: se decidieron los valores de las distribuciones *a priori* para el reclutamiento y la abundancia inicial por edad para el nuevo modelo de evaluación propuesto (SCAA). También se decidió fijar la variabilidad de la capturabilidad del estudio ya que su estimación en el modelo era muy pobre.
- Capturabilidad del estudio en función de la abundancia: sobre la base de los resultados de los diferentes modelos, se decidió utilizar la capturabilidad en función de la abundancia sólo para la edad 1.

Revisión de los puntos de referencia límite

- B_{lim}:: Estimación de un nuevo B_{lim} durante la reunión del CC de junio de 2018 basada en los resultados de la evaluación aprobada durante esta reunión siguiendo las directrices del Enfoque Precautorio de la NAFO.

- F_{lim}: Estimación de un nuevo F_{lim} durante la reunión del CC de junio de 2018 basada en los resultados de la evaluación aprobada durante esta reunión siguiendo las directrices del Enfoque Precautorio de la NAFO.

Los resultados de la evaluación aprobada se utilizaron para estimar los puntos de referencia límite durante la reunión del CC de junio de 2018. Se fijó SSB = 20 000 t como B_{lim}. La aproximación de F_{lim} se estimó en base a $F_{30\%SPR}$ calculada con los datos de 2015-2017, y su mediana fue 0.153. Se eligió este período debido al rápido cambio de los parámetros biológicos de la población.

El trabajo realizado por el SC03 permitió al CC cambiar el modelo de evaluación que se utilizará en junio de 2018.

Tarea 3: Apoyar la elaboración del plan de gestión plurianual para el bacalao en la Div.

3M. Desarrollar y probar la solidez de varias Reglas de Control de la Pesca (HCR) para el bacalao en la Div. 3M para lograr los objetivos de gestión que establezca la Comisión de Pesca.

Los objetivos, prioridades y directrices de esta Tarea estaban estrechamente relacionados con la labor del Consejo Científico y el Grupo de Trabajo Conjunto FC-SC-RBMS en 2018 y 2019. La mayor parte de las decisiones sobre el MSE bacalao de la 3M que estos Grupos de la NAFO han tomado se basaron en los resultados presentados por el SC03. La información detallada sobre los dos Grupos de Trabajo de 2018 se presentó en el Entregable D3.1 (septiembre 2018) y se presentó información detallada sobre los dos Grupos de Trabajo de 2019 en el documento entregable D3.2 (mayo de 2019).

El Consejo Científico de junio de 2018 acordó:

- Los datos que se utilizarán en el MSE y las directrices para desarrollar los Modelos Operativos MSE que se probarán.
- El caso base de referencia de los Modelos Operativos: establecido como el modelo de evaluación aprobado en 2018.

- Período de simulación: se decidió un período de 20 años para llevar a cabo las simulaciones.
- Directrices de las Reglas de Control (HCR): Se recomendó aplicar las mismas directrices para el bacalao 3M que las utilizadas durante el proceso de MSE del fletán negro 2+3KLMNO, incluido un HCR sin modelo.

El GT-RBMS de septiembre de 2018 acordó:

- El calendario de la MSE del bacalao 3M: comenzando en el otoño de 2018 y terminando en septiembre de 2019, antes de la Reunión Anual de la NAFO de septiembre de 2019.
- Las directrices generales para el trabajo del SC03: desarrollo de los Modelos Operativos y especificaciones de proyección, HCR a probar y propuesta de un conjunto completo de objetivos de gestión, estadísticas de rendimiento y riesgos.

Dos expertos externos invitados por la NAFO (Jim Ianelli y Daniel Howell) asistieron a la Reunión extraordinaria del CC 2019. En esta reunión se analizó el trabajo entre sesiones realizado por el SC03 y se decidió:

- Los métodos para estimar los diferentes componentes del conjunto inicial de los Modelos Operativos: Mortalidad natural, capturabilidad de las campañas, parámetros biológicos, selectividad, relación stock-reclutamiento y la generación de índices "observados" en las proyecciones.
- Acuerdos sobre puntos de referencia:
  - Puntos de referencia que se estimarán para cada Modelos Operativo e iteración.
  - $F_{30\%SPR}$ computado dinámicamente dentro de las proyecciones a futuro (usando, en cada año, el promedio de los tres años más recientes) para ser usado como un proxy para $F_{MSY}=F_{lim}$.
  - Se acordó que el SSB_{2007} se usaría como B_{lim}.
- Los HCR candidatos a ser probados: Model-Free Slope (MFS), Model-Free Target (MFT), F=0 y trigger/20%, es decir, una tasa de extracción constante del 20%, o algún otro valor, que se reduce gradualmente cuando el índice de biomasa del stock cae por debajo de un valor desencadenante (como una posibilidad si el tiempo lo permite).
- Primeras propuestas de un conjunto completo de Objetivos de Gestión/Estadísticas de desempeño de la gestión/Riesgos.
- El CC identificó 28 escenarios prioritarios que se presentarán en el GT-RBMS de abril de 2019.

La reunión del GT-RBMS de abril de 2019 analizó los resultados de los escenarios prioritarios acordados por la Reunión Extraordinaria del CC de Enero 2019 y concluyó:

- Que considerando el desempeño del conjunto inicial de MSE, era poco probable que la MSE produjera algún resultado que satisficiera el borrador de criterios de desempeño. Por lo tanto, se acordó centrar los esfuerzos en ofrecer asesoramiento durante la reunión del CC de junio de 2019 sobre la base de un modelo de evaluación en lugar de seguir desarrollando el MSE.
- El Equipo Técnico del SC03 seguirá desarrollando el modelo Dependiente de la Densidad (DD) y los escenarios de reclutamiento bajo para septiembre de 2019.
- El GT-RBMS debería reunirse antes de la Reunión Anual de la NAFO de 2019 para considerar cómo proceder, incluyendo un calendario revisado si la decisión es de continuar.

La reunión del GT-RBMS de septiembre de 2019 analizó los resultados finales de los escenarios acordados por la reunión del CC de enero de 2019 y concluyó:

- Que el trabajo en el GT-RBMS sobre el MSE del bacalao 3M debe ser suspendido por el momento. Se llegó a esta conclusión sobre la base de la fuerte variabilidad observada en la dinámica de las poblaciones y los parámetros biológicos en el pasado, que crean dificultades sustanciales para elaborar simulaciones futuras realistas y el desarrollo satisfactorio de un HCR. El GT-RBMS reabriría la cuestión cuando el CC determine que las condiciones son tales que hay una probabilidad razonable de éxito.
- El GT-RBMS destaca la enorme cantidad de trabajo que se ha dedicado a este proceso, en particular por parte del Equipo Técnico (SC03), cuyos esfuerzos y buena calidad de trabajo fueron reconocidos con gratitud. Aunque esta labor no ha dado lugar a un éxito inmediato, se han adquirido muchos conocimientos y experiencia, que serán de gran utilidad para cualquier proceso futuro de MSE.
- En lo que respecta a los futuros procesos de MSE, el GT-RBMS señaló que se habían encontrado importantes dificultades para cumplir el calendario establecido para los procesos de MSE tanto para el bacalao 3M como para el Fletán negro 2+3KLMNO. El GT-RBMS recomienda que los plazos establecidos para los futuros procesos de MSE sean realistas, teniendo en cuenta la gran cantidad de trabajo que se requiere. Se debe asignar suficiente tiempo y capacidad humana para el desarrollo del trabajo técnico, la revision, comunicación con los actores pertinentes e información de los resultados.

3 RÉSUMÉ EXÉCUTIF

Objet du contrat spécifique

L'objectif de cette étude spécifique est de fournir à la Direction Générale des Affaires Maritimes et de la Pêche (DG MARE) et au Conseil scientifique de l'Organisation des Pêches de l'Atlantique du Nord-Ouest (OPANO) une analyse technique et scientifique pour:

- Remédier aux lacunes du modèle d'évaluation actuel, identifiées par le Groupe de Travail de l'OPANO sur les stratégies de gestion basées sur les risques (GT-SGBR) (OPANO Comité des Pêches/Conseil Scientifique 15/02), le Conseil Scientifique (CS) (NAFO SCS 15/12) et la Commission de la Pêche (NAFO/FC 15/23) en 2015.
- Soutenir le développement du processus de référence 3M pour le cabillaud au sein de l'OPANO.
- Développer et tester la robustesse des différentes règles de contrôle des captures (HCR) pour la morue dans la division 3M pour atteindre les objectifs de gestion qui seront établis par le Comité de Pêche. Pour atteindre ces objectifs, trois tâches différentes ont été conçues :

<u>Tâche 1</u>. Organiser un atelier axé sur le modèle d'évaluation actuel et l'incertitude des projections pour la morue de la Division 3M.

<u>Tâche 2</u>. Soutenir l'élaboration de l'évaluation comparative pour la morue dans la division 3M.

<u>Tâche 3</u>. Soutenir l'élaboration du plan de gestion pluriannuel pour la morue dans la division 3M.

L'objectif de ce résumé est de présenter les principaux résultats de chaque tâche de projet ainsi que les conclusions et les décisions concernant l'évaluation de la stratégie de gestion (MSE) de la morue dans la Division 3M, prises par le Conseil Scientific de l'OPANO et le Groupe de Travail de l'OPANO sur la Gestion des Stocks de la Morue (OPANO GT-SGBR), sur la base de ces résultats.

Principaux résultats des tâches

<u>Tâche 1</u> : Organiser un atelier axé sur le modèle d'évaluation de 2015 et l'incertitude des projections pour la morue dans la Division 3M afin de remédier aux lacunes identifiées par le groupe de travail de l'OPANO sur les stratégies de gestion basées sur le risque (GT-SGBR), le Conseil Scientifique et la Commission des Pêches en 2015.

L'atelier s'est tenu à Vigo du 21 au 23 mars 2017. Les résultats de cette tâche ont été détaillés dans le rapport de l'atelier envoyé à l'EASME le 9 mai 2017 (livrable D1.1.).

Les principaux résultats de l'atelier ont été des propositions soumises à la réunion du Conseil Scientifique de juin 2017 et des recommandations pour le processus d'évaluation comparative. Toutes les propositions et recommandations ont été approuvées par le Conseil Scientifique.

Propositions soumises à la réunion de juin 2017 du Conseil Scientifique (CS).

1. L'atelier a proposé que la prochaine évaluation utilise les valeurs des entrées de la dernière année dans les projections au lieu de la moyenne habituelle des trois dernières années, afin de réduire l'impact de la tendance dans les paramètres biologiques. Il a également recommandé que la prise en compte de l'incertitude soit étudiée de manière plus approfondie avant d'envisager sa mise en œuvre.

Conclusions de la réunion du CS de juin 2017 : Il a été convenu d'utiliser dans les projections les valeurs de la dernière année par âge pour les paramètres biologiques en raison de la tendance à la baisse marquée de ces paramètres, et d'utiliser la moyenne des trois dernières années pour la sélectivité, car la sélectivité à l'âge a varié sans tendance ces dernières années.

2. L'atelier a proposé une nouvelle méthode d'estimation du risque dans les projections 3M pour la morue.

La nouvelle méthode résout les problèmes soulevés par le Comité des Pêches en 2015 en mesurant le risque associé à la pêche d'un TAC unique, au lieu de mesurer le risque associé à une distribution des TAC comme cela se faisait dans le passé. L'atelier a trouvé cette procédure plus raisonnable puisque la gestion se fait sur la base d'une valeur déterministe unique du TAC (la médiane de la distribution des TAC).

Conclusions de la réunion du CS de juin 2017 : Le CS a convenu d'utiliser la nouvelle méthode de projection et la mesure du risque proposées lors de l'atelier pour tous les stocks qui utilisent une évaluation intégrant l'incertitude.

Ces deux propositions approuvées par le CS ont résolu les principales lacunes identifiées par le GT-SGBR, le Conseil Scientifique et le Comité des Pêches en 2015.

Recommandations pour le processus d'analyse comparative 2018. Outre les propositions, l'atelier a formulé une série de recommandations techniques sur les paramètres biologiques, les points de référence, le modèle d'évaluation et la capturabilité, à discuter dans le cadre du processus d'évaluation comparative de l'année suivante.

Conclusions de la réunion du CS de juin 2017 : Le CS a approuvé toutes les recommandations de l'atelier concernant l'analyse comparative 2018 pour la morue 3M.

Tâche 2 : Soutenir le développement de l'analyse comparative de l'évaluation pour la morue dans la Division 3M.

Un des objectifs de cette tâche était d'organiser un atelier pour résoudre les problèmes de lecture de l'âge. Cet atelier a eu lieu à Vigo les 8 et 9 novembre 2018. Les résultats de cet atelier ont été détaillés dans un rapport envoyé à l'EASME le 6 février 2018 (livrable D2.1).

L'atelier a montré des progrès significatifs dans la correspondance entre les lecteurs, en particulier lorsque l'on compare uniquement les otolithes à motif clair et les lecteurs les plus expérimentés. L'atelier a conclu que l'interprétation des lectures d'âge n'est significativement différente que lorsque les otolithes à motif peu clair sont utilisés. Ces différences ont été bien identifiées et semblent être occasionnelles certaines années. Des

recommandations ont été faites pour résoudre ces problèmes à l'avenir. En attendant, il a été recommandé de poursuivre l'application des ALK de l'enquête aux distributions commerciales de longueur dans l'évaluation de la morue 3M.

Une réunion du CS via WebEx a eu lieu le 13 mars 2018 afin d'examiner les données disponibles et il a été décidé que les meilleures données sur la morue 3M seraient utilisées dans les futures analyses de la morue 3M. Les séries chronologiques des données commerciales et des données des campagnes scientifiques ont été examinées. Les principaux résultats de cette réunion ont été la décision de raccourcir la période d'évaluation, et donc de n'inclure que les données à partir de 1988, et de corriger certaines erreurs dans les données utilisées dans les évaluations précédentes. La décision de raccourcir la période d'évaluation a été prise parce qu'il y avait peu de données avant 1988 et que leur qualité n'était pas bonne.

La réunion d'analyse comparative s'est tenue à Lisbonne (Portugal) du 9 au 13 avril 2018. Trois experts externes invités par l'OPANO (Carmen Fernández, Jim Ianelli et Mike Palmer) ont participé à la réunion. Les résultats de cette réunion ont été détaillés dans le rapport envoyé à l'EASME le 9 mai 2018 (livrable D2.2). Les principales conclusions du CS, après analyse de tous les documents de travail du SC03, étaient :

Modèles d'évaluation

Quatre modèles d'évaluation différents ont été présentés lors de la réunion d'analyse comparative : Bayesian XSA, Bayesian SCAA, SAM et GADGET. Plusieurs scénarios explorant différentes configurations de modèles ont été exécutés.

Les derniers passages du Bayesian XSA et du SCAA ont montré une meilleure adéquation aux données de l'enquête et les résultats des deux modèles étaient similaires. La plus grande flexibilité du SCAA a été considérée par le CS comme un avantage par rapport au XSA, ce qui en fait un outil d'évaluation plus puissant, et il a été recommandé comme base de l'évaluation de Juin 2018 pour ce stock.

Paramètres du modèle

- Valeur M : La conclusion finale de la réunion d'analyse comparative a été d'utiliser un vecteur de M (variable par âge et constante pour toutes les années) comme auparavant dans les modèles bayésiens, avec un CV de 15 %.
- Ogives de maturité : la réunion d'analyse comparative a décidé d'utiliser dans l'évaluation les ogives de maturité dérivées des données des campagnes scientifiques de l'UE.
- Précédents de l'évaluation actuelle : les valeurs des distributions antérieures pour le recrutement et l'abondance initiale par âge pour le nouveau modèle d'évaluation proposé (SCAA) ont été décidées. Il a également été décidé de fixer la variabilité de la capturabilité de l'enquête puisque son estimation dans le modèle était très faible.
- Capturabilité issue des campagnes scientifiques en fonction de l'abondance : sur la base des résultats des différents modèles, il a été décidé d'utiliser la capturabilité en fonction de l'abondance pour l'âge 1 uniquement.

Révision des points de reférence limites

- B_{lim} : Estimation d'un nouveau B_{lim} lors de la réunion du CS de juin 2018, sur la base des résultats de l'évaluation approuvée lors de cette réunion, conformément aux lignes directrices de l'Approche de Précaution (AP) de l'OPANO.
- F_{lim} : Estimation d'un nouveau F_{lim} lors de la réunion du CS de juin 2018 sur la base des résultats de l'évaluation approuvée lors de cette réunion, conformément aux lignes directrices de l'OPANO sur l'approche de précaution.

Les résultats de l'évaluation approuvés ont été utilisés pour estimer les points de référence limites lors de la réunion du CS de juin 2018. La SSB = 20 000 t a été fixée comme B_{lim}. La valeur de remplacement de F_{lim} a été estimée sur la base de $F_{30\%SPR}$ calculée avec les données de 2015-2017, et sa médiane était 0.153. Cette période a été choisie en raison de l'évolution rapide des paramètres biologiques du stock.

Les travaux réalisés par le SC03 ont permis au SC de modifier le modèle d'évaluation à utiliser en Juin 2018.

Tâche 3 : Soutenir l'élaboration du plan de gestion pluriannuel pour le cabillaud dans la Div. 3M. Développer et tester la robustesse des différentes Règles de Contrôle des Captures (HCR) pour la morue dans la Division 3M afin d'atteindre les objectifs de gestion qui seront établis par le Comité des Pêches.

Les objectifs, les priorités et les lignes directrices de cette tâche sont étroitement liés aux travaux du CS et du Groupe de Travail conjoint CS-CP SGBR en 2018 et 2019. La plupart des décisions que ces groupes de l'OPANO ont prises concernant la MSE de la morue 3M étaient basées sur les résultats présentés par le SC03. Des informations détaillées sur les deux Groupes de Travail 2018 ont été présentées dans le document D3.1 (septembre 2018) et des informations détaillées sur les deux groupes de travail 2019 ont été présentées dans le livrable D3.2 (mai 2019).

Le CS de juin 2018 a donné son accord pour:

- Les données à utiliser dans la MSE et les lignes directrices pour élaborer les Modèles Operatifs (MO) à tester.
- Le scénario de référence des MO : établi comme le modèle d'évaluation approuvé en 2018.
- Période de simulation : une période de 20 ans a été décidée pour la réalisation des simulations.

- Les lignes directrices des Règles de Contrôle des Captures (HCR) : Il a été recommandé d'appliquer les mêmes lignes directrices pour la morue 3M que celles utilisées lors du processus MSE du flétan noir 2+3KLMNO, y compris un HCR sans modèle.

Le GT-SGBR de septembre 2018 a donné son accord pour :

- Le calendrier des MSE pour la morue 3M : débutant à l'automne 2018 et se terminant en septembre 2019, avant la réunion annuelle de l'OPANO de septembre 2019.
- Les lignes directrices générales pour le travail du SC03 : développement des Objectifs de Gestion et de spécifications de projection, HCR à tester et proposition d'un ensemble complet d'objectifs de gestion, de statistiques de performance et de risques.

Deux experts externes invités par l'OPANO (Jim Ianelli et Daniel Howell) ont participé à la Réunion extraordinaire du CS de 2019. Cette réunion a analysé le travail intersessionnel effectué par le SC03 et a pris des décisions :

- Les méthodes d'estimation des différentes composantes de l'ensemble initial des Modéles Opératifs : La mortalité naturelle, la capturabilité issue des campagnes scientifiques, les paramètres biologiques, la sélectivité, la relation entre les stocks et les recrues et la génération d'indices "observés" dans les projections.
- Les accords sur les points de référence :
  o Points de référence à estimer pour chaque Objectif de Gestion et itération.
  o $F_{30\%SPR}$ calculé dynamiquement dans les projections à venir (en utilisant, pour chaque année, la moyenne des trois dernières années) à utiliser comme proxy pour $F_{MSY}=F_{lim}$.
  o Il a été convenu que SSB_{2007} serait utilisé comme B_{lim}.
- Les candidats HCR à tester : Model-Free Slope (MFS), Model-Free Target (MFT), F=0 et trigger/20%, c'est-à-dire un taux de récolte constant de 20%, ou une autre valeur, qui est réduite progressivement lorsque l'indice de la biomasse du stock tombe en dessous d'une valeur de déclenchement (comme possibilité si le temps le permet).
- Premières propositions pour un ensemble complet d'Objectifs de Gestion (OG)/statistiques de performance(PS)/Risques.
- Le CS a identifié 28 scénarios prioritaires qui seront présentés lors de la réunion du GT-SGBR d'avril 2019.

La réunion d'avril 2019 du GT-SGBR a analysé les résultats des scénarios prioritaires convenus par la Réunion extraordinaire du CS 2019 et a conclu:

- Que, compte tenu des performances de l'ensemble initial de MSE, il est peu probable que la MSE produise des résultats qui satisfassent aux critères de performance provisoires. Par conséquent, il a été convenu de concentrer les efforts sur la fourniture de conseils lors de la réunion du CS de juin 2019 sur la base d'un modèle d'évaluation au lieu de développer davantage la MSE.
- L'équipe technique (SC03) continuera à développer le modèle de mesure de la densité et les scénarios de faible recrutement pour septembre 2019.
- Le GT-SGBR devrait se réunir avant la réunion annuelle de l'OPANO de 2019 pour examiner la manière de procéder, y compris un calendrier révisé si la décision doit être maintenue.

La réunion de septembre 2019 du GT-SGBR a analysé les résultats finaux des scénarios convenus lors de la réunion de janvier 2019 du Conseil Scientifique et a conclu :

- Que les travaux du GT-SGBR sur la MSE de la morue 3M devraient être suspendus pour le moment.
  Cette conclusion est basée sur la forte variabilité observée dans le passé de la dynamique des stocks et des paramètres biologiques, qui crée des difficultés substantielles pour le développement de simulations réalistes à l'avenir et la mise en place réussie d'un HCR. Le GT-SGBR rouvrirait la question lorsque le CS déterminera que les conditions sont telles qu'il existe une probabilité raisonnable de succès.
- Le GT-SGBR souligne l'énorme travail qui a été réalisé dans ce processus, en particulier par l'équipe technique (SC03), dont les efforts et la bonne qualité du travail ont été reconnus avec gratitude. Même si ce travail n'a pas abouti à un succès immédiat, il a permis d'acquérir beaucoup de connaissances et d'expertise, ce qui sera un atout pour tout futur processus de MSE.
- En ce qui concerne les futurs processus de MSE, le GT-SGBR a noté que des difficultés importantes ont été rencontrées pour respecter le calendrier fixé pour les processus de MSE tant pour la morue 3M que pour le flétan noir 2+3KLMNO. Le GT-SGBR recommande que les calendriers fixés pour les futurs processus MSE soient réalistes, en tenant pleinement compte de la très grande quantité de travail nécessaire. Il convient de prévoir suffisamment de temps et de ressources humaines pour l'élaboration des travaux techniques, l'examen, la communication avec les acteurs concernés et la présentation des résultats.

Le CS de juin 2018 a accordé :

- Les données à utiliser dans la MSE et les lignes directrices pour élaborer les Modèles Opératifs (MO) à tester.
- Le scénario de référence des MO: établi comme le modèle d'évaluation approuvé en 2018.
- Période de simulation : une période de 20 ans a été décidée pour la réalisation des simulations.
- Les lignes directrices des règles de contrôle des captures (HCR) : Il a été recommandé d'appliquer les mêmes lignes directrices pour la morue 3M que celles utilisées lors du processus MSE du flétan noir 2+3KLMNO, y compris un HCR sans modèle.

4 INTRODUCTION

The Executive Agency for Small and Medium-sized Enterprises (EASME) has commissioned the AZTI led consortium (AZTI, AGROCAMPUS, CEFAS, IEO, IPMA, IMARES, IRD, MRAG) for the Framework Contract EASME/EMFF/2016/008 for the "provision of scientific advice for fisheries beyond EU waters". The present technical report refers to the Specific Contract (SC) Nº 3 under this framework, "Support to a robust model assessment, benchmark and development of a management strategy evaluation for cod in NAFO Division 3M".

Purpose of the specific contract

The purpose of this specific study is to provide the Directorate-General for Maritime Affairs and Fisheries (DG MARE) and the Northwest Atlantic Fisheries Organization (NAFO) Scientific Council with technical and scientific analysis to:

- Address the shortcomings of the current assessment model, identified by the NAFO Working Group on Risk Based Management Strategies (WG-RBMS) (NAFO FC/SC 15/02), the Scientific Council (SC) (NAFO SCS 15/12) and the Fisheries Commission (FC) (NAFO/FC 15/23) in 2015.
- Support the development of the 3M cod benchmark process within NAFO.
- Develop and test the robustness of various Harvest Control Rules (HCRs) for cod in Div. 3M to achieve the management objectives to be established by the FC.

The scope of the study is the cod stock in Division 3M of NAFO.

Structure of the report

The structure of SC03 final report is as follows: First, the report presents the different Tasks that were carried out to achieve each of the objectives established in the Project. Then, the results of the Tasks for each of the objectives are presented in detail. A final point presents the milestones achieved, the problems faced and the possible 3M cod MSE future work to solve the current problems. Annex A includes a Table summarizing the meetings held during the Project and Annex B the list of deliverables of the Project and the corresponding NAFO documents in which they were presented. The link for the scientific documents produced by SC03 for each of the main Tasks are also presented.

5 RESULTS

Task 1

Objectives and achievements of Task 1

Task 1. Organise a workshop focusing on the current assessment model and the uncertainty in the projections for cod in Division 3M.

In order to support a robust full assessment for cod in Div. 3M, there were 4 areas that the workshop needed to address:

1.1. Revision of the currently available input data for the assessment with the aim to improve the quality of the stock assessment. **This Task was successfully completed with the work done during the workshop and the benchmark meeting (Task 2). Some errors were found in the input data that have been corrected.**

1.2. Revision of the R code of the current assessment model. This code has been fine-tuned in recent evaluations (NAFO SCR 15/033); however, an in-depth review and debug of the code is necessary. **The 2017 assessment model code was revised and used in the assessment of that year. A new code was developed in Task 2 due to the change of assessment model in 2018.**

1.3. Suggestion of potential alternatives to estimate natural mortality (M). **Different options were presented to estimate M, both by the assessment models or externally taking into account the biological characteristics. The option adopted at the benchmark meeting was to estimate M within the approved assessment model.**

1.4. How to implement the uncertainty in the catch projections. This issue was pointed out by the FC at its meeting in 2015 (NAFO/FC 15/23). **With the work contributed by the Project, the way in which uncertainty is incorporated into the projections as well as the way to estimate the risk of being below B_{lim} or above F_{lim} for a given TAC have been improved.**

Results of Task 1

The workshop was held in Vigo during March 21st – 23rd 2017. The results of this Task have been detailed in the workshop Report sent to the EASME on May 9th 2017 (Deliverable D1.1) and presented during the June 2017 SC meeting (**NAFO SCS 17/07**).

Workshop Conclusions:

The results of the workshop can be summarized in proposals submitted to the SC and reviewed during the June 2017 meeting, and recommendations to be carried out during the benchmark process.

Proposals submitted to the June 2017 SC meeting. These proposals are explained in detail in the NAFO SCR 17/017.

1. The workshop **proposed** that the next assessment used the final year values of the inputs in the projections instead of the usual mean of the final three years, to reduce the impact of the trend in biological parameters. It also recommended that accounting for uncertainty must be studied in more depth before considering its implementation.

   Marked decreasing trends in the values of the biological parameters cause problems in projections, because the inputs used for the projected years usually are overestimated, leading to an overestimation of the projected SSB and the associated TAC for a given F. Next year, the F associated to the proposed TAC must be greater than those assumed the previous year to catch the last year approved TAC. To reduce the impact of this overestimate in the projections results, the suggestion was to use the weights and maturity ogives of the last year as inputs in the projections instead of the usual mean of the last three years.

   The inputs of the projections have no uncertainty incorporated except in the case of the maturity ogive. Uncertainty in the projections' inputs to account for possible changes in biological parameters from one year to the next was also analysed during the workshop. This was done by examining the interannual changes observed in past years and considering the correlation observed between these variables.

   Conclusions of the June 2017 SC meeting: Due to the marked decreasing trend shown for the biological parameters (mean weight in catch, mean weight in stock and maturity ogive) in the last years, it was agreed to use the final year value as inputs for these parameters in the projections. In the case of the selectivity (partial recruitment), the decision was to use the last three years' mean because there is no trend in the last years.

   It was agreed that the use of uncertainty in the inputs of the short-term projection needs further in-depth analysis, and therefore this inputs uncertainty was not used during this meeting.

2. The workshop **proposed** a new method to estimate risk in the 3M cod projections. The new method measures the risk associated with fishing a unique TAC instead of a distribution of TACs as was done in the past.

   This procedure was seen as a more reasonable one since the management is done based on a single TAC, and therefore, it is more likely that managers are interested in knowing the risk that fishing that single TAC creates. Projections as done in previous years applied an F (e.g. F_{lim} or $3/4F_{lim}$) to each of the 5000 iterations, resulting in a distribution of TACs (5000 different TACs) for each projection scenario. The workshop's proposed method is to take the median of these 5000 TACs (this is the TAC that would be used to provide advice if that projection scenario was the basis for the advice) and to apply this unique TAC in each of the 5000 iterations. This will result in 5000 different Fs corresponding to catching the unique TAC in each of the 5000 iterations. The risk of F being above F_{lim} can then be directly estimated by comparing the resulting F with F_{lim} iteration by iteration.

   Conclusions of the June 2017 SC meeting: The Scientific Council agreed to use the new projections method and risk measure proposed in the workshop for all stocks that use an assessment with uncertainty.

Recommendations for the 2018 benchmark process:

1. The workshop **recommended** to further investigate the inclusion of variability in the biological parameters (mean weight in catch, mean weight in stock and maturity ogive) used in the projections.

2. The workshop **recommended** further investigation during the benchmark process to determine the best inputs to calculate F_{lim}.

3. The workshop **recommended** the benchmark process explore estimating M outside the stock assessment model, keeping in mind that this change might have a strong impact on other aspects, such as the Reference Points values.

4. The workshop **recommended** that the benchmark process consider alternative ways of extending the plus group (e.g. additional data disaggregation or alternative stock assessment models).

5. The 3M cod XSA Bayesian assessment model included the plus group age (8+) as part of the tuning indices. The standard XSA did not use the index of the plus group in the assessment. The workshop **recommended** that, because the benchmark process was going to explore the possibility of expanding the plus group, that this issue be explored at the same time.

6. There was a potential inconsistency between the plus group abundance estimation in the stock assessment and the specification of the plus group abundance in the projections. The workshop recommended some **alternative** stock assessment models, with the plus group abundance estimation consistent with the projection model, be tested in the benchmark process.

7. Abundance-based catchability was used in the assessment for ages 1 and 2 (power model for catchability). With the available information, it was not clear if this dependence should be included and it was **recommended** that the appropriateness of the estimation of these parameters in the assessment should be studied in more depth during the benchmark process.

Conclusions of the June 2017 SC meeting: The SC endorsed all the workshop recommendations for the 2018 3M cod benchmark. During the meeting, the dates and venue of the benchmark were discussed. In the September 2017 SC meeting, the date (April 9th-13th 2018) and the venue (Lisbon, Portugal), as well as the benchmark agenda, were approved.

These conclusions of the SC were included in the June 2017 meeting report (**NAFO SCS 17/16 Rev)**. One of the recommendations of the workshop solved the problems of how to estimate the risk of TACs in the projections. This had a direct implication in the projection results and advice made by the SC for 3M cod, as can be seen in the assessment document (**NAFO SCR 17/038**).

List of documents of Task 1 in order of appearance

González-Troncoso, D., F. González-Costas, S. Cerviño, R. Alpoim, A. Pérez Rodríguez, C. Fernández, C. Hvingel and M. Mandado, 2017. Report of the NAFO Cod 3M Workshop current assessment and projection uncertainties. 21-23 March 2017. Centro Oceanográfico de Vigo, Spain. NAFO SCS Doc. 17/07, Serial No. N6661.
https://www.nafo.int/Portals/0/PDFs/sc/2017/scs17-07.pdf?ver=2017-08-11-165653-233

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González-Troncoso, D., 2017. Assessment of the Cod Stock in NAFO Division 3M. NAFO SCR Doc. 17/038, Serial No. N6693.
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Task 2

Objectives and achievements of Task 2

Task 2. Support the development of the benchmark assessment for cod in Div. 3M.

The following Tasks needed to be performed to support the Division 3M cod benchmark assessment foreseen within NAFO at the latest for April 2018:

2.1. Organization of a benchmark workshop to review all information available (ecosystem and fisheries data, stock distribution, model parameters, assessment model, forecast method, review of the reference points, etc.) dealing with the single stock assessment method as per NAFO SCS 16/14 Rev. **The Project organized the SC 3M cod benchmark meeting in Lisbon and financed the participation of several members of the SC03.**

2.2. Support the benchmark process on:

2.2.1. Assessment of Input Data:

- Ageing and Age Length Keys (ALKs): investigate inconsistencies in age readings between readers and institutes. This investigation should include an exchange of otoliths. **Some inconsistencies were identified among the different readers. A common ageing protocol needs to be implemented. Some measures to try to solve these inconsistencies in the future have been proposed, but they could not be applied during the Project time.**
- Analyse the variability in the biological parameters (i.e. age at maturity, mean weights, etc.) observed in recent years. **The variability of the biological parameters of this stock has been studied and found to be closely related to abundance. A density-dependent method has been developed to include this variability in projections.**
- Prepare the available assessment input data, taking into account the results of the above points. **This Task was successfully completed with the work done during the workshop (Task 1) and the benchmark (Task 2). Some errors were found in the input data that have been corrected.**

2.2.2. Model parameters:

- Explore the possibility of expanding the plus group. **The possibility of expanding the plus group was studied during an intersessional SC meeting, and the conclusion was that it would be very difficult to get the age distributions data before 2008. This is because the ALKs**

used in commercial compositions are not available. Therefore, this possibility was not considered further.

• Explore the possibility of changing the priors of the current assessment. **Changes in the existing priors, especially those related to recruitment, were analysed and approved. In 2007, a prior with a median recruitment of 15 000 was established. However, recruitment observed in the period 2009-2012 was much larger than 15 000. To reflect that, a new prior with a median of 45 000 was adopted at the benchmark meeting.**

2.2.3. Assessment models: Explore alternative assessment models including multispecies models. **Four different assessment models were analysed, including a multispecies one (GADGET). The final runs of the Bayesian XSA and SCAA showed better fits to the survey data and the results of both models were similar. The greater flexibility of the SCAA was considered by the SC to be an advantage over the XSA, making it a more powerful assessment tool, and it was recommended as the basis of the June 2018 assessment for this stock.**

2.2.4. Review of the Limit Reference Points:

• B_{lim}: B_{lim} was changed to 20 000 tons in the 2018 June meeting due to the change in the assessment model and the consequent revised perception of the stock.

• F_{lim}: $F_{30\%SPR}$ was established as the best F_{lim} proxy. The FC requested in 2016 that the SC analyse whether the F_{lim} value for 3M cod was underestimated and to revise, if required, the relevant fishing mortality and biomass reference points appropriately.

The limit reference points of this stock had been reviewed and changed.

Results of Task 2

The Consortium, through Specific Contract 03, supported the organization of the benchmark meeting, providing the venue for the meeting, and the participation of Consortium Experts inside the EU delegation. A total of six people attended the meeting through the Consortium, and two more SC03 participants were funded by the European Commission.

2.1. *The organization of a benchmark workshop to review all information available (ecosystem and fisheries data, stock distribution, model parameters, assessment model, forecast method, review of the reference points, etc.) dealing with the single stock assessment method as per NAFO SCS 16/14 Rev. The benchmark workshop should be open to external experts. Stakeholders may also be invited to the workshops to provide information for the analysis to be performed.*

The NAFO 3M cod benchmark process began in March 2018 with a SC meeting on the data available to perform the assessment of the cod of the Div. 3M (March 13th 2018). The benchmark was held in Lisbon (Portugal) from April 9th to 13th 2018. Members of the Secretariat of NAFO and members of two Contracting Parties of NAFO (Canada and EU) attended the meeting, as well as three external experts invited by NAFO (Carmen Fernández, Jim Ianelli and Mike Palmer) and a stakeholder representative.

The benchmark final report is in NAFO SCS 18/18. The results of the different Tasks to achieve the Project second objective were the following:

2.2. *Support the benchmark process on:*

2.2.1. *Assessment of Input Data:*

• *Ageing and Age Length Keys (ALKs): investigate inconsistencies in age readings between readers and institutes. This investigation should include an exchange of otoliths.*

To solve the age-reading problems, a workshop was held in Vigo during November 8th and 9th 2018. The results of this workshop were detailed in a report sent to EASME on February 6th 2018 as Deliverable D2.1. The main recommendations and conclusions of the workshop were the following:

The workshop **recommendations** for future work were:

• Implementation of quality assessment and quality control in the laboratories involved in age reading of cod.

• Explore if otoliths of "low" quality are not related to a specific cohort. An otolith exchange based on cohorts rather than years should be done.

• An otolith exchange with otoliths from the 2009 cohort to find out why they were read differently.

• Store a reference otolith collection for future.

The workshop **recommendation** on the ALKs to use in the assessment was:

Looking at the results of the workshop, the problems were well identified and seem to be occasional in some years. Due to the short time of the workshop, it was not possible to solve all the problems. Another impediment was that one reader (IIM), one of the most experienced on 3M cod, was not available during the workshop and was also not available in months thereafter. The workshop therefore recommended that, until these problems are resolved, the survey ALKs continue to be applied to the commercial lengths.

• *Analyse the variability in the biological parameters (i.e. age at maturity, mean weights, etc.) observed in recent years.*

This Sub-task was mainly covered during the March 2017 workshop (Task 1.1). During the benchmark meeting, a Working Paper written by Project members

about the impact of this variability on the estimation of Reference Points was presented, as explained in the benchmark report (NAFO SCS 18/18). Work has been done by Project members on modelling this variability for use in the long-term projections of the MSE under Task 3 of this Project.

• *Prepare the available assessment input data, taking into account the results of the above points.*

Data to be used: An SC meeting via WebEx took place on March 13th 2018 in order to decide the 3M cod data to be used in the benchmark. The time series of both commercial and survey data were reviewed and presented during this meeting (NAFO SCR 18/001). The meeting report is in SCS 18/04. The main results of 3M cod input data from this SC meeting were the following:

• Time period to run the assessment: 1988-2016.

• SC catch estimates for 2011 and 2012: set taking the median of the prior over the catches for these years used in the last approved assessment.

• 2002-2005 catch at age abundance: we have no catch abundance during these years, but it is not going to be estimated at this moment.

• Years in which discrepancies between the Sum of Products (SoP) of numbers and weight at age in the commercial catch sampling and the total catch weight greater than 10% occurred: it was decided to adopt a common method to estimate the mean weights at age in the catches and the catch at age abundance. If the SoP is more than 1.10 or less than 0.90, the former numbers will be raised to the approved total catches for these years.

• For the period 2013-2016, it was agreed to update the abundance and the mean weights at age in the catch with a modification of the United Kingdom length distributions and the inclusion of new available Norwegian samples.

• Corrected transform values for the stock mean weights at age and for survey abundance at age in 1988 to 2004 will be used.

• Plus group to be used: 8+.

• Maturity ogives: current EU survey maturity ogives.

• Estimation of M: three different scenarios to be presented in the benchmark: (a) constant for all ages and years; (b) mean vector estimated for all size-dependent methods varying by age and constant in time; and (c) the age/year matrix of M estimated in the update GADGET model. These three alternatives were based on the results of the study presented (NAFO SCR 18/003) and in the results of the GADGET model (NAFO SCR 18/025).

M value: The three options approved by the March SC meeting were applied during the benchmark meeting to different assessment models. The final conclusion of the benchmark was to use a vector of M (variable by age and constant for all years) as prior in the Bayesian models with a CV of 15%.

Maturity ogives: a comparison of maturity ogives based on the EU survey information and those based on the commercial information was presented during the benchmark (NAFO SCR 18/031). Preliminary results showed that the survey maturity ogives and the commercial ones are quite consistent. Based on these results, the benchmark decided to use in the assessment the maturity ogives derived from the EU survey data.

2.2.2. *Model parameters:*

• *Explore the possibility of expanding the current plus group.*

The March 2017 3M cod workshop recommended that the benchmark process consider alternative ways of extending the plus group (e.g. through disaggregation of historical data or by using alternative stock assessment models). Currently the plus group is 8+ but the numbers in the 8+ group have increased in the most recent years.

Individual ages up to 16+ are available for the period 2008-2016 in catch data and 1988-2016 in the survey data. Although it will be possible to use these new disaggregated data up to age 16 in the future, it is quite unlikely that the historical catch series prior to 2008 can be disaggregated.

The default approach will be to use the current 8+. The study of an older plus group is considered a secondary problem and will be deferred.

• *Explore the possibility of changing the priors of the current assessment.*

A final conclusion on this topic was not reached during the benchmark. More work was done and presented in the June 2018 SC meeting. The preliminary results were the following:

Different scenarios were run and results showed the same problem as that encountered during the June 2017 assessment: changing the priors of the Bayesian XSA changed the results. The main change in the priors was for recruitment. In 2007, a prior distribution with a median recruitment of 15 000 was established. After the large recruitments of 2009-2012, a median recruitment value of 45 000 was considered by the benchmark to be more representative for this population.

• *Catchability depending on abundance.*

Based on the results of different models, it was decided to use the catchability dependent on the abundance only for age 1, which is the only age with significant dependency on abundance.

2.2.3. *Assessment models:*

• *Explore alternative assessment models including multispecies models.*

Four different assessment models were presented during the benchmark: Bayesian XSA, Bayesian SCAA, SAM and GADGET (multispecies model). Model configurations and results for the Bayesian XSA are available in NAFO SCR 18/029, for the Bayesian SCAA in NAFO SCR 18/030, for SAM in NAFO SCR 18/004, and for the GADGET model in NAFO SCR 18/024.

Several scenarios, changing the inputs of each model, were run. Based on the results, the final conclusions of the benchmark were the following:

Different formulations of the models in some cases gave very different results and often indicated lack of fit to the data. Analyses were focused on the Bayesian XSA and SCAA. The final two runs of the Bayesian XSA and SCAA showed better fits to the survey data, and results of the two models were similar to each other. The greater flexibility of the SCAA in estimating the parameters of the assessment was considered to be an advantage over the XSA, making it a more powerful assessment tool. In addition, more testing was conducted for the SCAA model during the benchmark than for the other models. Considering all these issues, the SC recommended a Bayesian SCAA to form the basis of the assessment for this stock, pending the sensitivity analyses (modifications to the prior distributions aiming to increase robustness). This sensitivity analysis was carried out and presented during the June 2018 SC meeting. This work was completed and the model structure, including the modifications to the prior distributions, was adopted by the SC and applied to assess the stock and provide advice for 2019. The June 2018 SC meeting Report is in NAFO SCS 18/19 and the final Bayesian SCAA model approved to assess the stock is in NAFO SCR 18/042.

2.2.4. Review of the Limit Reference Points:

No major progress on this point had been made due to lack of time. Many of the issues related to the Limit Reference Points were postponed to be discussed at the June 2018 SC meeting. The benchmark discussions on the Limit Reference Points were as follows:

A Working Paper was presented by Project members during the benchmark meeting calculating the Reference Points based on the ICES recommendations, with the objective of comparing the resulting values of the Limit Reference Points following the directives of NAFO and ICES. The results are reflected in the benchmark report (NAFO SCS 18/18). The B_{lim} estimates were quite similar, since the definition of this point in NAFO and ICES is quite similar. The greatest differences were observed in the F_{lim} values since the definition of this point is quite different between NAFO and ICES.

The conclusions of the benchmark were:

• B_{lim}: B_{lim} was established at 20 000 tons in the June 2018 SC meeting based on the results of the assessment approved during this meeting and following the NAFO PA guidelines.

• F_{lim}: A new F_{lim} would be estimated during the June 2018 SC meeting based on the results of the assessment approved during this meeting, following the NAFO PA guidelines. In the benchmark, no information was presented to change the current SC approved F_{lim} proxy ($F_{30\%SPR}$).

The approved assessment results were used during the June 2018 SC meeting to estimate the limit reference points (NAFO SCS 18/19). The stock recruit scatterplot was examined to find the SSB below which no good recruitments have been observed. This SSB (20 000 t) was set as B_{lim}. F_{lim} was estimated based on $F_{30\%SPR}$, calculated with the 2015-2017 data as 0.153 (median). This period was chosen due to the rapid change in biological parameters in the stock.

In the benchmark agenda, there was a point to deal with the issue of the projections, but, due to lack of time, it was not possible to examine the projections of the 3M cod based in the assessment models presented. This point was going to be developed during the June 2018 SC meeting.

Some topics of Task 3 of the SC03 were also included in the benchmark agenda:

A literature review of different Model-Free HCRs was presented to inform the SC of the different types of Model-Free HCRs. This study included the pros and cons of each of the revised HCRs. The study was presented as an SCR (NAFO SCR 18/002) and was important to help decide a Model-Free HCR for this stock.

An attempt was made during the benchmark to define possible Operating Models (OMs) based on the greatest sources of uncertainty observed in the assessments presented. Due to lack of time, little progress has been made on this point.

List of documents of Task 2 in order of appearance

NAFO, 2018. NAFO Scientific Council Flemish Cap (NAFO Div. 3M) Cod Stock Benchmark Assessment Meeting. 09–13 April 2018. Instituto Português do Mar e da Atmosfera (IPMA), Lisbon, Portugal. NAFO SCS Doc. 18/18, Serial No. N6841. https://www.nafo.int/Portals/0/PDFs/sc/2018/scs18-18.pdf

González-Costas, F., D. González-Troncoso, A. Ávila de Melo and R. Alpoim, 2018. 3M cod assessment input data. NAFO SCR Doc. 18/001, Serial No. N6778. https://www.nafo.int/Portals/0/PDFs/sc/2018/scr18-001.pdf

NAFO, 2018. Report of the review of input data for 3M cod benchmark assessment. 13th March 2018 via WebEx. SCS Doc. 18/04, Serial No. N6783. https://www.nafo.int/Portals/0/PDFs/sc/2018/scs18-04.pdf

González-Costas, F. and D. González-Troncoso, 2018. Cod 3M Natural Mortality. NAFO SCR Doc. 18/003, Serial No. N6780.
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Pérez-Rodríguez, A. and F. González-Costas, 2018. Estimates of predation and residual mortality for the Flemish Cap cod. NAFO SCR Doc. 18/025, Serial No. N6809.
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Sampedro, P., D. Garabana, and F. Saborido-Rey, 2018. Validation of Cod maturity ogive in NAFO 3M. Effect of the reproductive cycle momento on ogive estimation. NAFO SCR Doc. 18/031, Serial No. N6817.
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González-Troncoso, D., C. Fernández and F. González-Costas, 2018. Bayesian SCAA model for the 3M cod. NAFO SCR Doc. 18/030, Serial No. N6816.
https://www.nafo.int/Portals/0/PDFs/sc/2018/scr18-030.pdf

Brunel, T., 2018. Exploratory assessment of the cod 3M stock using SAM. NAFO SCR Doc. 18/004, Serial No. N6781.
https://www.nafo.int/Portals/0/PDFs/sc/2018/scr18-004.pdf

Pérez-Rodríguez, A. and D. González-Troncoso, 2018. Update of the Flemish Cap multispecies model GadCap as part of the EU SC05 project: “Multispecies Fisheries Assessment for NAFO”. NAFO SCR Doc. 18/024, Serial No. N6808.
https://www.nafo.int/Portals/0/PDFs/sc/2018/scr18-024.pdf

NAFO, 2018. Report of the Scientific Council Meeting. 01-14 June 2018. Halifax, Nova Scotia. NAFO SCS Doc. 18/19, Serial No. N6849.
https://www.nafo.int/Portals/0/PDFs/sc/2018/scs18-19.pdf

González-Troncoso, D., C. Fernández and F. González-Costas, 2018. Assessment of the Cod Stock in NAFO Division 3M. NAFO SCR Doc. 18/042, Serial No. N6833.
https://www.nafo.int/Portals/0/PDFs/sc/2018/scr18-042.pdf

Andrés M., D. García and A. Urtizberea,2018. Model-free HCR: literature review for NAFO Cod 3M. NAFO SCR Doc. 18/002, Serial No. N6779.
https://www.nafo.int/Portals/0/PDFs/sc/2018/scr18-002.pdf

Task 3

Objectives and achievements of Task 3

Task 3. Support the development of the multiannual management plan for cod in Div. 3M:

It has not been possible to develop a successful multiannual management plan for cod in Div. 3M that meets the risks approved by the WG-RBMS. The main problem encountered is the great variability in recruitment and biological parameters presented in this stock.

Progress in the MSE process was expected to happen after June 2018, following the completion of the 3M cod benchmark and the review of the NAFO Precautionary Approach Framework (PAF) by the PAF WG.

Because of the scale of the work as proposed by the 2015 WG-RBMS (NAFO FC/SC 15/02) ensuring that the results of different analyses and alternative scenarios were examined, a new set up of the different actions to develop a successful multiannual management plan for cod in Div. 3M and the MSE was needed. In order to support the MSE process, and with the guidance provided for the process by the WG-RBMS, the following Tasks were performed:

3.1. Design of a multiannual management plan for cod in Div. 3M

3.1.1. Define the most appropriate Operating Models (OMs) and HCRs to be tested in the 3M cod MSE taking into account the results of the study of Specific Contract No. 2 under Framework Contract No. MARE/2012/211. **Twenty seven (27) different OMs had been developed and implemented under three different HCRs.**

3.1.2. Develop different sets of performance statistics to evaluate the system reaching the management objectives. This should be done in close cooperation with DG MARE and EASME. **Different performance statistics had been proposed to measure the objectives and risk limits established by WG-RBMS.**

3.2. Carry out quantitative simulations to evaluate the achievement of the management objectives under the different HCRs. **The simulations of 88 scenarios, resulting from the combination of the different OMs with the HCRs, were carried out and their performance statistics presented in relation to the objectives and risks established by the WG-RBMS.**

Unfortunately, none of the HCRs tested met the management objectives set. The risk of this happening was already pointed out in Deliverables 3.1 and 3.2.

Future work should better define and select the possible OMs to be tested as well as HCRs to be considered that allow the closure of the

fishery when the risk of falling below B_{lim} is large. In this case, and due to the biological characteristics of this stock, finding an HCR that meets the established management objectives and risk is not an easy task and will require a lot of work and time.

Results of Task 3

The Consortium, through Specific Contract 03, was nominated by the SC and the WG-RBMS as the Technical Team responsible for performing all intersessional work and presenting its results.

3.1. *Design of a multiannual management plan for cod in Div. 3M*

June 2018 SC meeting

The June 2018 SC meeting discussed some points of the 3M cod MSE plan and agreed the following (NAFO SCS 18/19, pages 38-39):

The base case reference OM was set as the model assessment approved in the June 2018 SC meeting. The development of other OMs to be tested should consider the following guidelines:

- Possible OMs with alternative M priors and/or CVs.
- Possible OMs with different groups of qs if necessary.
- Model scenarios with alternative assumptions on recruitment.
- Possible OMs considering auto-correlated, inter-correlated and/or density-dependent impacts on weights and maturities.

A 20-years period was decided for carrying out the simulations (2018-2037). MSE performance statistics should reflect short-, medium- and long-term objectives.

The observation model to generate the future data should take into account the auto-correlation of the survey indices.

Reference points should be determined by each operating model independently and should be consistent within them. The reference points should be based on Maximum Sustainable Yield (MSY), if possible.

With regards to the Harvest Control Rules (HCRs) to be developed, it was recommended to apply the same guidelines for 3M cod as the ones used during the 2+3KLMNO Greenland halibut MSE process, including a Model-Free HCR.

August 2018 WG-RBMS

During the August 2018 WG-RBMS meeting, the general objectives and the new schedule of the 3M cod MSE were agreed. The calendar included the dates, actions and people responsible for each of the actions (Technical Team, NAFO Secretariat, SC or WG-RBMS). The final report is presented in NAFO/COM-SC 18/02. The calendar started in fall 2018 and ended in September 2019, prior to the September 2019 NAFO Annual Meeting.

The responsibilities of the SC03 were to develop OMs and Projection Specifications, test HCRs, and propose a full set of Management Objectives (MO), Performance Statistics (PS) and risks, that will be revised by the SC and the WG-RBMS. The table below shows actions required to complete the MSE process, the parties responsible for their completion, and indicative dates to enable the process to be completed by September 2019.

Dates	Action	Responsibility
Fall 2018	Development of OMs	Analysts
	Testing of HCRs	Analysts
	Development of Projection Specifications	Analysts
	Proposals for full set of MO/PS/Risks	Analysts
	Develop Trials Specification document (to be updated as the process continues)	Analysts
	Arrange repository for code and results	Secretariat
January 2019	Review OMs and approve initial set of OMs, including the acceptability of their conditioning, and/or suggest further refinements	SC
	Approve Projection Specifications	SC
	Comments on initial set of HCR (if required)	SC
Feb-March 2019	Test initial/refined HCRs using initial/refined set of OMs	Analysts
March 2019	Review initial MSE results	WG-RBMS
	Update and possibly finalize PS and associated risk levels	WG-RBMS
	Indicate where improvements in performance are most required to guide analysts in revising HCRs	WG-RBMS
April – May 2019	Implement HCR improvements	Analysts
	Propose plausibility weightings for OMs (if required)	Analysts
June 2019 SC Meeting	Review refined OMs and approve final set of OMs, including the acceptability of their conditioning	SC
	Review results from refined HCRs and cull those HCRs not needing further consideration	SC
	Agree plausibility weightings of OMs (though subject to endorsement by RBMS)	SC
Summer 2019. (potentially an additional day on the end of the SC June meeting or separate July meeting, possibly by Webex)	Finalize PS and associated risk levels –	WG-RBMS
	Endorse plausibility weightings of OMs	WG-RBMS
August-early September 2019	Run tests of a final set of HCRs on finalized OMs and prepare consolidated results –	Analysts
preceding NAFO AM 2019	Review results of MSE for revised HCRs & recommendation to Commission –	WG-RBMS

One possible problem expressed by members of the SC03, the SC and the WG-RBMS is that the new approved schedule could be very ambitious due to the short time available to complete it and, therefore, it presented a certain risk that SC03 Task 3 could not be completed on the WG-RBMS planned date.

After the decisions of the SC and the WG-RBMS in September, SC03 Task 3 participants met via Skype in order to start the work in this Task following the time schedule set by the WG-RBMS. The following topics were discussed:

- the workplan to carry out all Tasks,
- responsibilities of each of the SC03 members in the workplan and
- technical aspects of the first set of candidate OMs and HCRs.

Work done between September 2018 and the January 2019 SC meeting

Between September 2018 and January 2019, several meetings were carried out among different members of the SC03 Team to discuss and decide upon different settings and technical aspects of the MSE for the 3M cod. A total of 6 OMs to simulate the system dynamics in the past, 4 OMs for the projections, 3 possible candidate HCRs (2 Model-Free and F=0) and a set of Management Objectives and Performance Statistics were presented in the January 2019 SC meeting. They are described in the NAFO SCRs 19/001, 19/002, 19/003, 19/004 and 19/005.

January 2019 SC extraordinary meeting

The SC revised the different proposals presented by SC03 (NAFO SCRs 19/001 - 19/005) and decided on the initial set of most appropriate Operating Models (OMs) and HCRs to be tested in the 3M cod. The agreed initial set of OMs was 4 OMs for past dynamics, 3 for the biological parameters in the future and 3 about the stock-recruitment relationships for estimating the recruitment in the future. Two priority Model-Free HCRs were also agreed for their development with different parameters values. The table below presents the agreed scenarios:

	Variables	Scenarios		
HCR settings	HCR names	Model-Free Slope (MFS)	Model-Free Target (MFT)	
	α (tuning parameter in HCR)	1.0 (A10)	1.5 (A15)	
	Constraint on inter-annual TAC change	None (Cnone)	±20% (C20)	
	Starting Point*	TAC_{2019}=17500 t (SP0)	TAC_{2019}–25%=13125 t (SP25)	
OM settings	Natural Mortality (until year 2017)	**M vector (MV)**	M GADGET (MG)	M Steps (MS)
	Recruitment (2018 onwards)	**Bin Ricker (BR)**	Hockey Stick (HS)	Low Bin Ricker (HR)
	Biological parameters (2018 onwards)	**Random walk (RW)**	3 Years Mean (3Y)	Density Dependent (DD)
	Groups q (age groups for survey catchability)	**Flat Shape (F)**	Dome Shape (D)	

* *When the management strategy is applied for the first time (i.e. for year 2020 in the MSE simulation), the TAC obtained from the HCR is calculated starting from this value instead of starting from the adopted 2019 TAC.*

Base-Case OM in bold

The SC also approved the Reference Points, the methodology proposed to estimate the indices of the survey in the future, 4 possible HCRs (including F=0, no fishing) and proposed some possible Performance Statistics (PS). All the technical decisions taken by the SC to develop the different OMs, HCRs and PS were described in detail in the January 2019 SC meeting report (NAFO SCS 19/04).

Due to lack of time to develop all the Tasks for the April 2019 WG-RBMS meeting, the SC agreed to focus the work on the development of a set of 28 priority scenarios

3.2. Carry out quantitative simulations to evaluate the achievement of the management objectives under the different HCRs.

April 2019 WG-RBMS meeting

The Technical Team worked on the January 2019 SC agreed priority scenarios, presenting all the results in the April 2019 WG-RBMS meeting in two different Working Papers. One showed the results of the scenarios run, and the other the proposals for the full set of MOs, PSs, Risks and their results. These Working Papers are included in the Report of the WG-RBMS meeting of April 2019 (NAFO COM-SC 19/01).

A total of 30 scenarios were presented including some scenarios to show the impact of the following changes on the results:

- setting a TAC constraint of 20% from one year to another,
- setting the TAC Starting Point for 2019 at 75% of the established TAC (so, 13125 tons instead of the established TAC of 17500 tons), and
- changing the HCRs parameter values.

The results showed that the Model-Free HCRs tested (Slope and Target) were not robust with regard to the Management Objectives approved by the WG-RBMS. The main problem was with the Management Objective for SSB which required that the probability of SSB falling below B_{lim} was less than 10%. In all the scenarios presented, there was more than 10% probability that the SSB in the short/medium term will fall below B_{lim}. These results were mainly due to the fact that very low recruitments have already been observed for the last 4 years. This means that in the short/medium term, the biomass decreases substantially regardless of whether the HCR tested produces low levels of catches.

The second PS measured the probability of the F being above F_{msy} for a given HCR. For this PS, the risk accepted by the WG-RBMS is 30%. In almost all the scenarios analysed, the risk of F being above F_{msy} was more than 30% in the short/medium term, even though the level of catches was very low. As mentioned above, this is because of the low recruitment observed between 2014 and 2017, which leads to very small levels of biomass produced.

Even with the zero-catches HCR (F = 0), in the short/medium term, the probability that the biomass is lower than the B_{lim} was hardly less than 10%. Therefore, any scenario that assumes that catches are greater than 0 would result in a probability that is higher than the admitted value of 10%.

These results, together with the great variability observed in biological parameters and recruitment levels and difficulties in simulating the variability in the projections, made it very difficult to find a robust HCR that meets the risk levels established by the WG-RBMS within the agreed time scale.

After looking carefully at the results, the WG-RBMS concluded that (NAFO COM-SC 19/01):

Considering the initial set of MSE results against the draft performance criteria and the high variability and biological parameters of the stock, WG-RBMS discussed the likelihood that the MSE will produce results that will satisfy the performance criteria and therefore the merit in continuing the MSE work for this stock. The WG-RBMS also noted that given the stock dynamics and characteristics, it may not be a suitable candidate for a MSE approach.

It was agreed that the Technical Team will continue its work, including the development of the DD model and the low recruitment scenario. The WG-RBMS will meet prior to the NAFO Annual Meeting to consider the results and determine appropriate next steps in the MSE process including a revised timeline if the decision is to continue development of the MSE. In the interim, it was agreed that the SC at its June 2019 meeting will provide advice for the stock in 2020, if the Technical Team has new results for some of the approved scenarios available in time for the June SC meeting, those results could be reviewed by the SC in June along with those presented in this meeting.

WG-RBMS will meet prior to the NAFO annual meeting to review the updated technical work, consider next steps including a revised timeline, if required, and formulate recommendations to the Commission.

These agreements implied changes in the priorities and in the approved calendar of the 3M cod MSE. Among the changes approved is that the WG-RBMS would have the next meeting in September 2019 just before the Annual Meeting.

To provide scientific advice in 2019 for 2020, the SC decided to carry out an "ordinary" assessment for the 3M cod during its June 2019 meeting. The SC Designated Expert to carry out this assessment is a member of SC03. Results of this assessment are presented in NAFO SCR 19/026 Rev.

One of the biggest problems identified in deliverables 3.1 and 3.2 that hampered the ability to achieve objective 3 of the SC03 Project was that the approved schedule for the 3M cod MSE was very ambitious due to the short time available to complete it. The complexity of the biological characteristics of this stock made it not feasible to find an HCR that satisfies the management objectives established by WG-RBMS (especially the objective about SSB being greater than B_{lim} with a probability of less than 10%) by September 2019.

The WG-RBMS also decided to continue working on the 3M cod MSE to present all the results of the scenarios already agreed in September to decide, with all the results on the table, what should be the next steps to follow in the NAFO 3M cod MSE.

September 2019 WG-RBMS meeting

In this meeting the results of 88 scenarios of the 89 agreed at the January 2019 SC meeting of were presented. New MSE simulations were performed intersessionally for scenarios not available in April, including OMs with settings as follows: historical natural mortality changing over time by two-year steps (MS), Historical Recruitment (HR), in which the current run of poor recruitment continues for several more years, and density-dependent for future biological parameters (DD). The results were included in the WG-RBMS report (NAFO COM-SC 19/05).

Some main conclusions from the new and previous results were:

- The results of all the scenarios analysed with catches showed that there is a high probability that the SSB will be lower than B_{lim} in the very short term. This probability was very high even in scenarios without fishing (F = 0) and with Low Recruitment (HR). This would imply the need to close the fishery in the very short term (2-3 years).

- Recruitment and biological parameters had shown very high variability in the historical period. There are considerable difficulties to simulate recruitment in a realistic way going into the future.

- MSE results from Density-Dependent (DD) scenarios for future biological parameters displayed lower uncertainty than 3 Years Mean (3Y) and Random Walk (RW) scenarios. However, the uncertainty associated with DD scenarios may be underestimated. On the other hand, the great uncertainty in projected outcomes under RW scenarios may be in part due to their difficulty in adequately capturing the behaviour observed in biological parameters in the past.

- MSE results of most of M-Steps (MS) scenarios for natural mortality showed much greater variability than for M-GADGET (MG) and M-Vector (MV) scenarios. To reduce this great variability, scenarios with weight-related natural mortality could be considered in the future. The DD scenarios presently developed for biological parameters did not include future density-dependent natural mortality.

- The low recruitment OM developed (labelled HR) assumed a fairly long period of low recruitment in the future. This may be pessimistic; however, a similar period of continuous low recruitment was observed in the past. In this low recruitment scenario, there is a high probability of falling below B_{lim}, even with F=0.

- The results showed that none of the HCRs tested so far meet the accepted risk levels for SSB below B_{lim} and F above F_{lim}. These HCRs need a reformulation and a much deeper study, both in their formulation and the values of the parameters. The new HCRs should allow the closure and opening of the fishery depending on the state of the resource (biomass levels, recruitments).

Based on the previous results, the WG-RBMS decided the following (NAFO COM-SC 19/05):

WG-RBMS concluded that work in WG-RBMS on the 3M cod MSE should be suspended for the time being. This conclusion was reached based on the strong variability observed in the stock dynamics and biological parameters in the past, that create substantial difficulties for developing realistic future simulations and successful development of an HCR. This situation, coupled with the low recruitment observed in recent years that will likely result in a strong decline of the stock biomass even without a fishery, implies that developing an HCR is not considered feasible at this stage. Reopening this issue in WG-RBMS should occur when SC determines that conditions are such that there is a reasonable probability of success.

WG-RBMS highlights the enormous amount of hard work that has gone into this process, particularly from the Technical Team, whose efforts and good quality of

their work were gratefully acknowledged. The MSE process has included additional meetings of SC with external invited experts and a very significant amount of intersessional work. As a consequence, even though this work has not resulted in immediate success, a lot knowledge and expertise has been gained, which will be an asset to any future MSE process.

Concerning future MSE processes, WG-RBMS noted that significant challenges were encountered in meeting the timetable set for the MSE processes for both 3M cod and 2+3KLMNO Greenland halibut. This resulted in insufficient time for adequate review and documentation of the results. WG-RBMS recommends that timeframes set for future MSE processes should be realistic, taking full account of the very large amount of work required. Sufficient time and human capacity should be allowed for the development of the technical work, review, communication with relevant actors and reporting of results.

List of documents of Task 3 in order of appearance

NAFO, 2018. Report of the Scientific Council Meeting. 01-14 June 2018 Halifax, Nova Scotia. Serial No. N6849 NAFO SCS Doc. 18/19.
https://www.nafo.int/Portals/0/PDFs/sc/2018/scs18-19.pdf

NAFO, 2018. Report of the NAFO Joint Commission-Scientific Council Working Group on Risk-Based Management Strategies (WG-RBMS) Meeting. 13-15 August 2018. London, United Kingdom. NAFO COM-SC Doc. 18/02, Serial No. N6852.
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NAFO, 2019. January 2019 NAFO Scientific Council Flemish Cap (NAFO Div. 3M) Cod Stock Management Strategy Evaluation (MSE). 28-31 January 2019. North East Atlantic Fisheries Commission (NEAFC) headquarters, London, UK. NAFO SCS Doc. 19/04, Serial No. N6911.
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NAFO, 2019. Report of the NAFO Joint Commission-Scientific Council Working Group on Risk-Based Management Strategies (WG-RBMS) Meeting. 21 September 2019. Bordeaux, France. NAFO COM-SC Doc. 19/05, Serial No. N7001.
https://www.nafo.int/Portals/0/PDFs/COM-SC/2019/com-scdoc19-05.pdf

6 LESSONS LEARNED AND FUTURE WORK

This section presents main problems, lessons-learned, and milestones achieved in this Project and outlines possible studies to be considered in the future.

Problems faced

The major challenge encountered during the development of the Project was to meet the time schedule set for the third task of the Project (MSE process). The schedule for Task 3 of Project SC03 was the same as established by the NAFO RBMS WG to complete the MSE of cod 3M. The approved schedule for the 3M cod MSE by the WG-RBMS was very ambitious; therefore, the risk of not being able to achieve Task 3 in time was quite high. This, added to the complexity of the biological characteristics of this stock (large variations of the biological parameters and difficulty in simulating possible future recruitments), made the task of finding an HCR that would fulfil the management objectives established by RBMS quite complicated.

Another problem was that the timetable established by NAFO for the cod 3M MSE was changed several times due to different problems encountered in the process. This resulted in new meetings and tasks that were very difficult to reallocate among the different SC03 Project participants to meet the new objectives and deadlines. The flexibility in changing schedules and tasks that exists in NAFO is much greater than in the EASME Specific Contracts and the Institutions that participate in the EASME Specific Contracts. This is aggravated when performing certain tasks of the projects depends on hardware (big computers) shared by many Institutions as in the case of the 3M cod MSE.

Lesson learned

The main lesson learned was that timeframes set for future MSE processes should be realistic, taking full account of the very large amount of work required and the problems that may appear in the process. Sufficient time and human capacity should be allowed for the development of the technical work, review, communication with relevant actors and reporting of results. The NAFO Greenland halibut MSE is another example of the problems that may occur when calendars are very tight or unrealistically ambitious. It was developed in one year, and nowadays the SC is facing several problems because of the rush with which the studies were done. In fact, there are several examples of MSE processes in other RFMOs that have been developed for several years, but not reached definitive results yet. The timeframes can be modified during the study due to difficulties in developing some tasks, which also constrains the development of the subsequent tasks. Therefore, a larger timeframe would give more flexibility to the study, and this will facilitate greater flexibility for scientists in the Project, as they also have other obligations during the timeframe of the Project.

Another lesson learned is that it is very useful for this kind of projects to involve new and external researchers to broaden the expertise and perspectives of a relatively small group such as the NAFO SC. Different points of view, knowledge and expertise

are very constructive and new ways to overcome problems and constraints could be used to solve some old problems.

Main achievements

Problems associated with the risk calculated in the projections, raised by the NAFO Commission in 2016, were solved and the new method used in this stock to estimate the risk in the projections was approved to be used in all the NAFO stocks using a Bayesian framework.

This Project helped understand the biology of this stock as well as its implications for managing the fishery. It also facilitated an in-depth review of all the historic data used in the cod 3M assessment.

The Project organized the SC 3M cod benchmark meeting in Lisbon and funded the participation of several members of the SC03. This was the first Benchmark organized by NAFO SC and some lessons were learned about how to organise this type of events and how external scientists can be involved in the affairs of the NAFO SC.

Four different assessment models were analysed, including a multispecies one (GADGET). The results of the Benchmark allowed changing the former Bayesian XSA 3M cod assessment model for the current more flexible Bayesian SCAA.

Although the main objective of Task 3, that was to find a robust HCR, has not been reached, progress has been achieved that will facilitate future work in this field. Progress made includes the development of density-dependent Operating Models and inclusion of recruitment as a parameter in the possible HCRs to be tested.

Future work

Input data

Age Length Key inconsistencies: Ageing and Age Length Keys (ALKs): Some inconsistencies were identified among the different otolith readers. A common ageing protocol needs to be implemented, but that was not possible during the Project. Measures proposed to try to solve these inconsistencies in the future are:

- Implementation of quality assessment and quality control (QA/QC) in the laboratories involved in age reading of cod.
- Explore if otoliths of "low" quality are not related to a specific cohort. An otolith exchange based on cohorts more than on years should be done.
- An otolith exchange made with otoliths from the 2009 cohort given by both commercial and survey ALKs to find out what happened and why they were read differently.
- Store a reference otolith collection for future.

Expanding the plus group: Currently the plus group is 8+. In the most recent years the numbers in the 8+ group have increased, being a substantial proportion of the stock nowadays. The possibility of expanding the plus group was studied by SC, and the conclusion was that expanding it would require a great effort and it would be very difficult to redo age distributions before 2008 because the ALKs used in commercial compositions are unknown.

Individual ages up to 16+ were available for the period 2008-2016 in catch data and 1988-2016 in the survey data. It is quite unlikely that the historical catch series prior to 2008 can be disaggregated. It will be possible to use these new disaggregated data up to age 16 in the future, when the disaggregated historical series of all inputs that begins in 2008 is long enough to carry out an assessment to compare the results with the assessment with the current plus group.

Short-term projections

Uncertainty in the short-term projections: An attempt to incorporate uncertainty in the inputs of the short-term projection was explored. During the June 2017 SC meeting it was agreed that this matter needed further analysis. This matter is nowadays a key point as the MSE process has been delayed and the advice of the next years will be given based on an assessment and short-term projections. This could be analysed in the future, for example, via a density-dependent model similar to the one used in the MSE process.

MSE process

Density-dependent model: A density-dependent Operating Model to estimate biological parameters was implemented with quite good results. It would be convenient to continue with the development and refinement of this type of OMs, including the estimation of other variables such as natural mortality.

Future Recruitment: Two different stock-recruitment relationships based on the SSB level were analysed during the MSE process. None of them fit well the observed data and these recruitment estimations presented different problems. Further analysis in order to estimate the recruitment in the future based on other variables must be explored.

Harvest Control Rules: Three different model-free (based on surveys) HCRs were examined during the MSE process, none of them reached the established objectives. Deeper analyses are needed for developing other HCRs that, for example, could allow closing the fishery when the stock is under a defined level and reopen it when the stock recovers.

Risk: Current risk levels for different MSE performance statistics should also be evaluated taking into account the risk of the F = 0 scenarios.

Future MSE work: It would be convenient for the cod MSE that the research continues during the next years even if the pace is lower than in recent years. This research

would benefit from the work done so far and would allow the SC to reopen the issue in the future. The continuity of these works will depend on the priorities of the Institutions related to the NAFO SC as well as availability of funding to carry out these works.

It is noted that the best MSE practices recommend devoting substantial time and effort to the development of a MSE process, not only of scientists but even of managers and stakeholders to understand the whole process and consequences of different decisions.

ANNEX A: LIST OF MEETINGS

Meeting	Location	Participation	Date	Documents	Deliverables
Kick off meeting and Task 1 Coordination meeting	Brussels	EASME/DGMARE + IEO + AZTI	11 May 2017		D0.1, D1.1
NAFO 3M cod Workshop on current assessment and projection uncertainties	Vigo	IEO + IPMA + IMARES + External Experts	21-23 March 2017	NAFO SCS 17/07 NAFO SCR 17/017	
June SC Meeting	Halifax	IEO + IPMA + SC	30 May-16 June 2017	NAFO SCS 17/16 Rev NAFO SCR 17/38	D1.1
Age readers' workshop	Vigo	IEO + IPMA + External Experts	8-9 November 2017		D2.1
SC Review of Input Data for 3M Cod Benchmark Assessment	WebEx	IEO + IPMA + IMARES + External Experts	13 March 2018	NAFO SCS 18/04	
SC 3M cod Benchmark	Lisbon	IEO + AZTI + CEFAS + IPMA + IMARES + SC	9-13 April 2018	NAFO SCS 18/18 NAFO SCRs 18/001, 002, 003, 004, 024, 025, 029, 030, 031	
Task 2 Coordination meeting	Brussels	EASME/DG MARE + IEO	14 May 2018		D2.2
June SC Meeting	Halifax	IEO + IPMA + NAFO SC	1-14 June 2018	NAFO SCS 18/19 NAFO SCR 18/042	D2.2
FC-SC WG-RBMS	London	IEO + IPMA + SC + FC	13-15 August 2018	NAFO COM-SC 18/02	D3.1
SC NAFO Div. 3M Cod Stock Management Strategy Evaluation (MSE)	London	IEO + AZTI + IPMA + SC	28-31 January 2019	NAFO SCS 19/04 NAFO SCRs 18/001, 002, 003, 004, 005	D3.2
FC-SC WG-RBMS	Brussels	IEO + AZTI + IPMA + SC + FC + EASME/DGMARE	10-12 April 2019	NAFO COM-SC 19/01	
Task 3 Coordination meeting	Brussels	EASME/DGMARE + IEO	6 May 2019		D3.2
June SC Meeting	Halifax	IEO + IPMA + SC	31 May-13 June 2019	NAFO SCR 19/026 Rev	D3.2
FC-SC WG RBMS	Bordeaux	IEO + IPMA + SC + FC + DGMARE	21 September 2019	NAFO COM-SC 19/05	
Final meeting	Brussels	EASME/DGMARE + IEO + AZTI	11 November 2019		D0.3, D0.4

ANNEX B: LIST OF DELIVERABLES

Del. no.	Deliverable name	Nature[1]	Dissemination level	Del. date[2]	Sent date	Requested in ToRs[3]	Document
D 0.1	Inception Report	R	EASME/ DGMARE	3 weeks	27/04/2017	Y	
D 1.1	Task 1 - Progress report + NAFO Scientific Council Research document	R + O	EASME/ DGMARE and NAFO SC	May 2017	09/05/2017	Y	NAFO SCS 17/07
D 2.1	Age readers' workshop Report	R	Internal	Dec. 2017	15/01/2018	A	Deliverable D.2.1
D 0.2	Interim Report	R	EASME/ DGMARE	12 months	13/05/2018	Y	
D 2.2	Task 2 - Progress report + NAFO Scientific Council Research documents	R + O	EASME/ DGMARE and NAFO SC	May 2018	09/05/2018	Y	NAFO SCSs 18/04, 18 NAFO SCRs 18/001, 002, 003, 004,025, 029,030
D 3.1	Report with the NAFO WG RBMS 2018 meeting conclusions	R	EASME/ DGMARE	TBD 2018	11/10/2018	A	NAFO COM-SC 18/02
D 3.2	Task 3 - Progress report + NAFO Scientific Council Research documents	R + O	EASME/ DGMARE and NAFO SC	May 2019	02/05/2019	Y	NAFO SCRs 19/001, 002, 003, 004,005
D 0.3	Draft Final report	R	EASME/ DGMARE	32 months	25/10/2019	Y	This document
D 0.4	Final Report and Executive Summary	R	EASME/ DGMARE	33 months		Y	

[1] Nature of the deliverable: **R** = Report, **O** = Other (specify).

[2] Measured in weeks or months from the date after the signature of the contract.

[3] If the deliverable was specifically requested in ToRs (Y = Yes; A = Additional).

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