Mémoire d'Habilitation à Diriger des Recherches

Présenté à l'Université De Nantes,

Soutenu le 22 septembre 2021


# Clara ULRICH

IFREMER, Direction Scientifique


---

# Pêcheries mixtes, captures accessoires et rejets dans la Politique Commune de la Pêche

## Exemple des pêcheries démersales en Mer du Nord

***Mixed fisheries, bycatch and discards in the Common Fishery Policy***
***Examples from the demersal fisheries in the North Sea***

---

**RAPPORTEURS :**

| | | |
|---|---|---|
| Pr. | Didier GASCUEL | HDR, Professeur, Institut Agro, Rennes |
| Dr. | Dorothée VINCENT | HDR, Chargée de mission, Office Francais de la Biodiversité, Brest |
| Dr. | Paolo GUIDETTI | Directeur de recherche, Stazione Zoologica Anton Dohrn, Naples, Italie |

**EXAMINATEURS :**

| | | |
|---|---|---|
| Dr. | Nicolas BEZ<br>***Président du jury*** | HDR, Directeur de recherche, Institut de Recherche pour le Développement, UMR MARBEC, Sète |
| Pr. | Brice TROUILLET | HDR, Université de Nantes, Laboratoire LETG, UMR 6554 CNRS |
| Dr. | Manuela AZEVEDO | Senior Scientist, Instituto Português do Mar e da Atmosfera (IPMA), Algès, Portugal |
| Dr. | Patrice GUILLOTREAU | HDR, Directeur de recherche, Institut de Recherche pour le Développement, UMR MARBEC, Sète |

*Managing fisheries is just like rowing – you have to progress without knowing where you are going, and you realise you have reached the objective only after you have passed it!*

Freely requoted from David A. Anderson, Canadian Minister of Fisheries and Oceans (1997–99). Heard at the Summit of the Sea, Newfoundland, Sept 1997

---

# Avant-propos et Remerciements

Au-delà d'un "simple" mémoire d'HDR, une étape toujours importante dans la carrière d'un chercheur en France, ce manuscrit revêt une symbolique toute particulière pour moi, la mémoire d'une vie qui se termine alors qu'une autre vie commence. Il clôt en effet deux décennies (2000-2019) passées à Copenhague, décennies riches et productives en tous points de vue. Partie vers l'inconnu avec pas grand-chose d'autre qu'une thèse en poche, je suis revenue en France vingt ans après, avec quelques belles histoires scientifiques et familiales… Mais au-delà du changement géographique de lieu de vie, c'est le changement de périmètre professionnel qui est le plus marquant dans ce retour au pays. Recrutée à la Direction Scientifique de l'Ifremer, je suis ainsi passé d'un job très « vertical » - experte européenne pointue dans mon petit domaine des pêcheries mixtes, naviguant tout le long de la chaîne de la connaissance et de la transmission depuis le pêcheur au port jusqu'au commissaire européen à Bruxelles – à un job à l'inverse très « horizontal », découvrant la grande diversité de la science au sein d'Ifremer, et engrangeant progressivement une nouvelle connaissance d'un monde beaucoup plus vaste, des grands fonds jusqu'aux estuaires, de l'infiniment grand à l'infiniment petit. Ce manuscrit d'HDR m'a ainsi donné une occasion précieuse de fermer ces vingt années de « verticalité », de les coucher sur le papier pendant que la trace en était encore fraiche dans ma mémoire, de raconter leur histoire, mon histoire, alors que je navigue déjà vers une autre forme d'inconnu.

Mes premiers remerciements vont donc tout naturellement aux membres du jury qui ont accepté de lire et de commenter ce travail. Constituer ce jury n'a pas été si simple, pour moi qui arrivais de loin et connaissais finalement assez peu de gens dans le monde académique français… Mais ce fut justement l'occasion de sortir de mes murs, et je me réjouis de discuter avec tous en ce jour de soutenance. Je me permets une mention toute spéciale pour Didier Gascuel, qui fut mon directeur de thèse et (toujours) mentor… Il m'a ouvert les portes de la recherche il y a 25 ans, et pourra mesurer le chemin parcouru depuis!

Je remercie également tout particulièrement Anne Renault, directrice scientifique d'Ifremer, pour la chance qu'elle m'a donnée avec ce poste d'adjoint auprès d'elle, un alignement des planètes pour une nouvelle orientation de carrière et un retour en France quand l'envie s'en est fait sentir. Que l'ensemble de la Direction Scientifique d'Ifremer sache aussi combien j'apprécie de travailler avec eux.

Comme cette HDR raconte mes années danoises, mes pensées les plus chaleureuses vont vers tout mon réseau de collègues et amis de DTU Aqua, du CIEM, du CSTEP, de « Bruxelles » et de DiscardLess… Ils ne liront peut-être jamais ces lignes en français, mais je leur dois mes plus belles heures et mes plus grandes joies de science, et quelques nuits un peu raccourcies… devant un ordinateur ou au comptoir ☺

Enfin, je mesure avec émotion, et un peu de fierté, le parcours qui a été le mien, menant de front, et sans (presque) rien lâcher d'un côté ni de l'autre, une vie de chercheure internationale entre hôtels et aéroports, et une vie de mère de trois enfants, aujourd'hui adolescents et jeunes adultes bien dans leurs baskets… Je remercie ici avec amour mon « gentimari » Claude qui a fait tourner la maison, et mes généreux parents et beaux-parents qui ont si souvent fait les trajets entre la France et le Danemark quand il le fallait… et j'envoie un Stor Kram virtuel à mes copines « Bad Moms » de DTU Aqua avec qui les doutes sont devenus des fous rires ! Ainsi qu'à tous nos chers amis de Copenhague, nos chemins se recroiseront.

*kærlig hilsen*

# Pêcheries mixtes, captures accessoires et rejets dans la Politique Commune de la Pêche

# Exemples des pêcheries démersales en Mer du Nord

## Résumé

La majorité des pêcheries européennes capturent de multiples espèces à chaque opération de pêche (« pêcheries mixtes »), certaines étant ciblées et commercialisables, d'autres étant non désirées et souvent rejetées à la mer. Ces captures non désirées peuvent avoir un impact écologique important sur les populations concernées, et depuis longtemps des initiatives politiques et scientifiques s'attachent à trouver des solutions pour améliorer la sélectivité des pêcheries. Mais l'application et le succès de ces initiatives restent globalement mitigés, et les problèmes perdurent.

Depuis plus de 20 ans mes recherches s'intéressent à cette problématique des pêcheries mixtes, avec une approche très multi-disciplinaire et plus de 55 articles publiés. J'ai analysé à la fois des aspects scientifiques et techniques (caractérisation des types de pêcheries, modélisation bioéconomique, causes et quantités de captures accessoires, impact écologique, stratégies d'évitement, prise en compte dans l'évaluation des stocks halieutiques), des aspects politiques et réglementaires (rôles et incitations des régulations européennes, contrôle à distance de la pêche par caméras), et des aspects économiques et socio-culturels (comportement des pêcheurs, incitations positives, approches basées sur le résultat), dans une perspective double de recherche et d'expertise scientifique en appui à la politique publique européenne.

A travers une synthèse de mes travaux, mon HDR présentera ainsi un bilan des progrès et barrières passés et présents de la Politique Commune de la Pêche de l'Union Européenne en matière de durabilité des pêcheries mixtes. Plus particulièrement, on s'intéressera à l'obligation de débarquement (interdiction des rejets) entrée pleinement en vigueur en 2019, et au changement majeur de paradigme qu'elle devait induire dans la conception européenne de la gestion et du contrôle de la pêche.

Etant maintenant directrice scientifique adjointe de l'Ifremer et n'étant ainsi plus actuellement en position de développer et diriger directement de nouvelles thématiques de recherche moi-même, mon projet s'attachera plutôt à présenter des pistes pour de futurs développements de la politique européenne de la pêche, prenant aussi en compte les nouvelles menaces liées au changement climatique et à la montée des approches nationalistes dans la gestion de ressources collectives. Il discutera aussi du rôle de la science dans cette perspective, et des futurs besoins de recherche halieutique qui y sont liés.

Le manuscrit est écrit en anglais, avec une synthèse en français. Les numéros indiqués (#) renvoient à la liste de publications fournie en annexe 4.

# Summary

The majority of European fisheries catch multiple species during each fishing operation ("mixed fisheries"), some of which are targeted and marketable, while others are unwanted and often discarded at sea. These unwanted catches can have a significant ecological impact on the populations concerned, and political and scientific initiatives have long sought to find solutions to improve the selectivity of fisheries. However, the implementation and success of these initiatives have remained limited, and the problems persist.

For more than 20 years, my research has focused on this issue of mixed fisheries, with a very multi-disciplinary approach and more than 55 published articles. I have analysed several aspects, including scientific and technical aspects (characterisation of fishery types, bioeconomic modelling, causes and quantities of by-catches, ecological impact, avoidance strategies, inclusion in fish stock assessment), political and regulatory aspects (roles and incentives of European regulations, remote control of fishing by cameras), and economic and socio-cultural aspects (fishermen's behaviour, positive incentives, result-based approaches), in a dual perspective of research and scientific expertise in support of European public policy.

Through a synthesis of my work, this HDR manuscript will thus present an assessment of the past and present progress and barriers of the European Union's Common Fisheries Policy in terms of the sustainability of mixed fisheries. In particular, it focuses on the landing obligation (discard ban) that has come into full effect in 2019, and the major paradigm shift it was meant to bring about in the European approach to fisheries management and control.

Being now deputy scientific director of Ifremer and thus no longer in a position to directly develop and direct new research themes myself, my project rather focus on presenting avenues for future short and medium-term developments of the European fisheries policy, also taking into account the new threats linked to climate change and the rise of nationalistic approaches in the management of collective resources. It will also discuss the role of science in this perspective, and the related future fisheries research needs.

The manuscript is written in English, with a summary in French. The numbers indicated (#) refer to the list of publications provided in Appendix 4.

## Table des matières

# Pêcheries mixtes, captures accessoires et rejets dans la Politique Commune de la Pêche.

# Exemples des pêcheries démersales en Mer du Nord.

## Synthèse en Français

Cette HDR est présentée en anglais, par simplicité d'écriture eu égard à mes vingt années de carrière scientifique passées hors de France (2000-2019). Ci-dessous est donc fourni une synthèse de ce document en français.

### Chapitre 1 : Introduction

L'halieutique et la gestion des pêches est un sujet de recherche large et fascinant, incluant des facettes et des disciplines très différentes. La pêche est une activité économique qui dépend de ressources naturelles renouvelables, mobiles, et partagées. La pêche ne peut donc perdurer que si l'ensemble des conditions écologiques, économiques, politiques, sociales et techniques sont réunies. Sans poisson dans la mer, sans engins adaptés, sans marché ni consommateurs, pas de pêche. La gestion durable de la pêche doit donc prendre en compte l'ensemble du socio-écosystème, dans toute sa complexité.

L'une des difficultés majeures est l'existence des interactions techniques dans les pêcheries mixtes. La majorité des pêcheries dans le monde capturent plusieurs espèces et tailles de poissons simultanément, certaines ayant de la valeur et étant ciblées, d'autres étant indésirables ou non autorisées à la vente et, le plus souvent, rejetées à la mer. Ceci est particulièrement vrai dans les pêcheries démersales européennes, où les rejets sont souvent, et plus qu'ailleurs, liés à un accès inégal aux droits de pêche (quotas) à la fois entre états membres de l'Union Européenne et au sein de chaque état. L'impact écologique – et, de plus en plus, éthique – de ces rejets pose question depuis longtemps, mais les initiatives mises en œuvre depuis plusieurs années restent peu couronnées de succès et le problème perdure.

Cette problématique de la gestion des pêcheries mixtes, des captures accessoires et des rejets dans le cadre de la Politique Commune de la Pêche (PCP) a été mon fil rouge pendant mes vingt ans de recherche, d'abord en thèse à AgroCampus Ouest, Rennes, puis à l'Université Technique du Danemark (DTU Aqua).

Ce chapitre 1 rappelle le contexte général de mon travail. On rappelle d'abord les principaux concepts rencontrés dans ce document, et les enjeux de gestion majeurs qui s'y rapportent (section 1.1). La deuxième section fait un parallèle étonnant entre l'évolution de ma propre carrière scientifique et celle de la PCP, les phases de grands changements d'ambition et de complexification ayant largement coïncidé, aidées aussi en cela par les grandes orientations programmatiques de la recherche européenne (Programmes Cadres 5, 6, 7 et Horizon Europe). Cela m'amène à présenter la PCP plus en détail dans la section 1.3, mettant en avant que la plupart des maux d'aujourd'hui sont liés aux décisions d'hier, et que les réformes se suivent mais que les héritages historiques sont restés. Un chapitre spécial est dédié à l'article 15 de la réforme de la PCP de 2013, mettant en œuvre « l'obligation de débarquement » c'est-à-dire l'interdiction des rejets en mer, prévue pour être pleinement opérationnelle à partir de 2019. Finalement, la section 1.4 résume ma production scientifique en relation avec tous ces différents concepts, reliant mes 56 publications (marquées dans le texte **#** en référence à la liste de publication en Annexe 4) avec les grands sous-thèmes de recherche.

Trois de ces sous-thèmes sont ensuite traités dans les chapitres suivants.

## Chapitre 2 : De la difficulté de classifier et quantifier les interactions techniques

Ce sujet a été mon premier grand thème de recherche, puisqu'il fut déjà celui de ma thèse en France (1997-2000). Il a fait l'objet de certaines de mes premières publications (#7, 12, 16, 40, 42), mais il a surtout été préfigurateur de mes premières activités liant recherche et expertise au sein du CIEM (Conseil International pour l'Exploration de la Mer, ICES).

Telles qu'on les a introduites au chapitre précédent, les notions de « pêcherie », « flottille » ou « métier » ont un sens assez intuitif, car tout le monde se représente sans problème la diversité des engins de pêche, des maillages, des zones de pêche et des espèces remontées à bord. Cependant, la difficulté vient quand on veut définir et quantifier ces différents métiers, par exemple pour réguler un type d'activité, ou pour planifier la collecte de données et l'échantillonnage. En effet, même s'il y a des similarités techniques dans les types de pêche, l'impact de chaque pêcheur, de chaque marée, de chaque opération de pêche sur les ressources exploitées est en réalité unique, car des captures très différentes peuvent résulter de pêches apparemment semblables. Définir des groupes à partir de ces informations multi-dimensionnelles « d'intrants » (caractéristiques techniques de la pêche) et « d'extrants » (captures) peut donc être approché de plusieurs manières, et qui peuvent aussi varier en fonction de la question posée.

Le chapitre 2 décrit ainsi ces questions d'ordre méthodologique, qui ont donné lieu à de très nombreuses publications scientifiques en Europe vers le début des années 2000s, au moment de l'émergence du programme cadre pour la collecte de données halieutiques en Europe (DCF), par exemple pour les plans d'échantillonnage des observateurs à bord. On explique ainsi les choix, souvent subjectifs, faits entre définir les métiers sur la base du maillage ou sur la base des captures historiquement observées, et le manque souvent criant de corrélation entre les deux dans certaines pêcheries. Pour les études réalisées sur les profils de capture, de type cluster ou agrégation hiérarchique, on décrit aussi les difficultés liées au choix des données à analyser : débarquement ou captures totales ? proportions d'espèce en volume ou en valeur ? Combien d'espèces considérées comme potentiellement ciblées ?

Enfin, on s'attache à la sensibilité des résultats au choix de la méthode statistique, ainsi que du choix des paliers qui définissent le nombre de métiers retenus, comme illustré à la figure 2.2. La conclusion de ces nombreuses analyses publiées est qu'il n'existe pas de méthode simple et unique qui peut être utilisée de manière universelle pour définir les métiers, tant la variabilité de profils peut être grande. On observe d'ailleurs que la DCF s'est elle aussi maintenant éloignée de ce concept, considérant désormais des strates d'échantillonnage plus larges que le métier.

Le chapitre 2 se termine sur une illustration de la complexité des pêcheries démersales en Mer du Nord. Le groupe de travail du CIEM WGMIXFISH a défini l'existence de 42 flottilles (pays*type d'engin*taille de navire); opérant dans 29 métiers différents (engin*maillage*zone de pêche*type d'espèces) et ciblant 8 espèces démersales majeures réparties sur 18 stocks halieutiques.

## Chapitre 3: De la gestion au RMD des pêcheries mixtes

Le troisième chapitre s'attache au sujet le plus structurant des années intermédiaires de ma carrière de recherche, celui de la modélisation bioéconomique des pêcheries mixtes dans un souci de définir des scenarios de gestion compatibles avec le principe de RMD (Rendement Maximum Durable) (#2, 3, 8, 10, 13, 14, 32, 37, 43, 44, 46, 48, 49, 50).

Le RMD en tant qu'objectif de pêche durable est un concept ancien, initialement défini sur des analyses théoriques simplistes de populations isolées et biologiquement stables. La difficulté de le traduire en objectif quantitatif dans le monde réel, où les populations sont dynamiques et les interactions sont permanentes, a conduit à son abandon dans les années 70-80s, avant sa réhabilitation sur la scène internationale au début des années 2000s, faute d'avoir trouvé un remplaçant plus approprié (l'approche de précaution utilisée jusqu'alors dans les pêches européennes ayant démontré son incapacité à juguler la surexploitation chronique des stocks).

Dans un premier temps, je me suis attaché à transposer ce concept dans une approche pêcherie mixte (section 3.3). En 2006, j'ai proposé pour la première fois un modèle assez simple (appelé "FCube", "Fleets and Fisheries Forecast") pour quantifier les impacts des pêcheries mixtes sur les différentes espèces exploitées (aussi bien espèces cibles que captures accessoires), et ainsi étudier différents scenarios de gestion pour essayer d'atteindre les objectifs RMD pour plusieurs espèces en même temps. Partant de l'exemple des pêches conjointes de la morue et de l'églefin en Mer du Nord, j'ai ainsi montré que le stock de morue ne pourrait pas se rétablir tant que l'églefin était pleinement exploité, en raison des captures accessoires de morue supérieures au quota, et donc rejetées. Entre 2006 et 2012, j'ai beaucoup oeuvré au sein du CIEM pour rendre cette approche complètement opérationnelle et intégrée dans les avis scientifiques annuels sur les quotas de pêche, d'abord pour la Mer du Nord, ensuite pour les autres régions (Mer Celtique, Golfe de Gascogne..). Pour ce faire, il a fallu notamment changer les procédures standard d'agrégation et de bancarisation des données halieutiques (structure en âge, taux de rejets par métier), et ainsi assurer que les informations nécessaires soient annuellement disponibles et mises à jour pour tous les stocks et toutes les flottilles. (En partie) grâce à ce travail, quand la PCP a été réformée en 2013, il a été agréé de gérer les TACs (Totaux Autorisés de Capture) non plus en silos, dans des plans de gestion individuels stock par stock, mais dans une approche plus intégrée.

Dans un second temps, j'ai travaillé au sein de la dynamique européenne autour de l'adaptation et de la modernisation du concept RMD, tout en restant dans une approche stock par stock (section 3.4). L'amélioration des connaissances biologiques et des outils statistiques a conduit à une dynamique importante en Europe et au CIEM au début des années 2010s, pour proposer un cadre de gestion RMD plus flexible prenant en compte la variabilité annuelle des paramètres biologiques de chaque stock. L'idée centrale étant de s'attacher essentiellement à définir les zones de risques, où on ne veut pas être, plutôt que de chercher à définir exactement, mais vainement, le point précis de RMD. C'est ainsi que le concept des "MSY ranges" est né, c'est à dire un intervalle autour du point $F_{RMD}$ median, assurant au moins 95% du rendement maximum tout en minimisant le risque pour la biomasse de chuter en dessous de Blim (risque inférieur à 5%). Ainsi, depuis 2016, on met en place des plans de gestion multi-espèces et multi-annuels sur l'ensemble des zones de pêche européennes, c'est-à-dire un plan de gestion unique et unifié pour chaque région définissant des objectifs (RMD) et des intervalles (MSY ranges) pour chacun des stocks exploités conjointement.

Finalement, dans un troisième temps j'ai naturellement travaillé à joindre les deux initiatives pour proposer une approche de scénario de gestion pour les pêcheries mixtes compatible, dans la mesure du possible, avec les intervalles RMD de chaque stock (section 3.5). Nous avons développé plus avant le modèle FCube et proposé un scénario d'optimisation, visant à minimiser les risques de captures hors quotas tout en restant dans l'intervalle autorisé. Ce scénario est devenu le pivot central de l'avis CIEM sur les pêcheries mixtes (Figure 3.7 dans ce rapport HDR), et le suivi annuel des plans de gestion européens est à l'heure actuelle encore très largement basé sur le modèle que j'avais proposé en 2006.

## Chapitre 4: Approches techniques et politiques pour réduire les rejets et les captures accessoires.

Ce quatrième chapitre rassemble les travaux réalisés au cours des cinq dernières de ma carrière à DTU. Pendant ces années très productives, j'ai à la fois dirigé un projet de recherche européen, H2020 DiscardLess, ainsi qu'un projet national FEAMP danois (#1, 3, 5, 17, 21, 22, 23, 26, 27), encadré un post-doc (#30, 34, 35) et un doctorant (#18, 19, 24, 25, 28, 33), et présidé le CSTEP, le Conseil Scientifique, Technique et Economique pour la Pêche auprès de la Commission Européenne.

Ces travaux ont été largement réalisés dans une optique d'aide scientifique à la mise en oeuvre de l'obligation de débarquement, visant à (i) mieux comprendre les mécanismes techniques, économiques, écologiques et institutionnels qui induisent les rejets et ainsi (ii) proposer des options pour contribuer à la réduction de ces rejets.

L'introduction générale du chapitre présente d'abord les objectifs et enjeux majeurs du projet DiscardLess. On discute ensuite des principales causes de rejets, qui sont en fait très peu et très simples: Un poisson capturé est rejeté parce qu'il est soit trop petit, soit sans valeur marchande, soit abimé, soit, enfin, parce que le pêcheur n'a pas le droit de le débarquer (quota atteint ou espèce protégée). Par ailleurs, on explique que le rejet est un acte économiquement rationnel, étant donné que les coûts directs sont minimums, et certainement bien moindres que les coûts liés au tri, stockage et retour à terre, et que les coûts indirects, ceux de la surexploitation, ne sont pas internalisés. Ceci explique que au-delà des principes éthiques ou écologiques, il est économiquement difficile de diminuer les rejets.

La deuxième partie (section 4.2) fait un tour d'horizon des principales options d'évitement explorées dans le projet DiscardLess. Elles sont de deux types : les options techniques liées à la modification des engins de pêche, et les options tactiques liées à la modification des choix d'où et quand pêcher. Le doctorant et le post-doc ayant plus contribué à la recherche sur les options tactiques, celles-ci sont plus détaillées dans le rapport.

De ces nombreuses analyses techniques et tactiques, il ressort surtout deux conclusions majeures. La première conclusion est qu'il y a beaucoup d'options possibles pour réduire les captures accessoires, et qu'une pêche plus « propre » est possible. Mais dans la plupart des situations, aucune option n'est cependant à la fois unique, simple et complètement efficace ; toute option est donc un compromis entre des pertes et des profits… s'il y avait des solutions simples, nous les aurions déjà trouvées ! La deuxième conclusion est que même si des solutions existent, le système actuel n'offre souvent pas assez d'incitations positives pour que les pêcheurs y voient leur propre intérêt à les utiliser. Il en résulte un système essentiellement coercitif, sous contraintes réglementaires minutieuses mais qui, paradoxalement, sont souvent contournées. Pour espérer réduire les rejets, il est donc nécessaire d'imaginer un système de gestion plus incitatif, permettant un meilleur alignement des incitations et objectifs individuels des pêcheurs avec les objectifs collectifs et sociétaux de conservation.

C'est à cela qu'on s'attache dans la section 4.3, en détaillant les résultats encourageants d'expérimentations sociales grandeur nature conduites en association avec des pêcheurs danois au cours des dernières années. Ces approches, communément appelées Pêcheries Pleinement Documentées, sont une déclinaison de l'approche de gestion basée sur le résultat. Le principe est simple : en échange de plus de liberté technique et réglementaire sur les manières de pêcher, le pêcheur est tenu responsable de son impact sur les ressources, c'est-à-dire que l'ensemble de ses captures (débarquements + rejets) doivent être comptés dans son quota global. Pour ce faire, le pêcheur est tenu de documenter complètement ces captures, et d'assurer un moyen de vérification fiable et indépendant. Ceci a pris la forme d'observation électronique (Electronic Monitoring), un système de capteurs et de caméras à bord permettant de vérifier la véracité des captures déclarées (un peu au même titre que les « mouchards » des camions). Ces approches ont prouvé pouvoir être très puissantes, à la fois pour fournir une documentation fiable des captures totales et ainsi améliorer le suivi scientifique et l'évaluation des stocks de pêche, mais aussi, souvent, pour inciter les pêcheurs à des comportements plus vertueux en leur donnant plus de latitude pour optimiser la valeur marchande, ou le profit, de leur « impact maximum autorisé ». Ces expérimentations ouvrent ainsi la voie à un nouveau paradigme pour la gestion des pêcheries mixtes en Europe.

# Chapitre 5: Perspectives : la Politique Commune de la Pêche : nouveaux enjeux, nouvelles voies, et le rôle de la science

Ce dernier chapitre diffère des attendus habituels d'un chapitre prospectif d'une HDR, en raison de ma situation professionnelle particulière. Du fait de ma nouvelle position de directrice scientifique adjointe à Ifremer, je ne vais en réalité pas diriger des recherches en tant que tel dans un futur proche, ni les miennes ni celles de doctorants. J'ai donc choisi de terminer ce manuscrit par des réflexions sur les nouveaux enjeux de la Politique Commune de la Pêche, et sur l'aide possible que la science peut y apporter. Les enjeux décrits sont à la fois d'ordre politique (Brexit, landing obligation, plans de gestion), et d'ordre biologique et écologique (approche écosystémique des pêches, changement global).

Comme on l'a vu à propos de l'obligation de débarquement, on se doit toutefois de rester humble à propos de l'influence réelle de la science dans le monde politique de la gestion de la pêche européenne. Certes la science est largement consultée et écoutée au quotidien, et les relations entre science et décision sont, dans notre domaine, assez bien formalisées et transparentes grâce entre autres aux rôles d'interface majeurs joués par le CIEM et le CSTEP. Il n'en reste pas moins que l'avis scientifique est un élément parmi d'autres du processus consultatif et décisionnel complexe des institutions européennes, et à ce stade il reste difficile d'anticiper le degré d'implication des scientifiques dans la prochaine réforme de la PCP. Il est cependant essentiel de s'y préparer dès maintenant, afin d'apporter une vision holistique du socio-écosystème, basée sur une compréhension globale des enjeux écologiques et humains de la durabilité des pêches européennes.

# Mixed fisheries, bycatch and discards in the Common Fishery Policy.

# Examples from the demersal fisheries in the North Sea.

## 1 Introduction

Fisheries management is a wide and fascinating topic of research, because it involves so many facets. Fishing is an economic activity that depends on natural resources, those being characterized as being renewable, variable, mobile, and ownerless. Fishing exist thus through the interaction of multiple ecological, economic, political, human, social and technical components, and fisheries can only be sustained if each of its individual components is itself sustained. If there is no fish to be caught or no market where it can be sold, then there is no fishery. Secondly, managing fisheries is managing people (and not fish), while taking full consideration of their role in and impact on the marine ecosystem. Consider in addition the great deal of variability and unpredictability of the processes involved, and the impossibility to quantify fish populations with simple direct observations by the human eye (As one says *« Counting fish is just like counting trees – except that they are invisible and keep moving »*[1])… It appears then easily that robust knowledge on where we stand and where we are heading to is of major importance for the successful management of fisheries. In this regards, science plays a key role in helping managers and stakeholders understand the complex processes driving and linking all these facets together, and assessing the impacts of the political and social actions of the many actors involved.

Among the key sources of complexity is the issue of *technical interactions* in *mixed fisheries.* The majority of fisheries worldwide (not in terms of total tonnage given the high volumes caught by monospecific pelagic and industrial fisheries, but certainly in terms of number of vessels) are multi-specific (*mixed*), in that they catch multiple species and size classes of fish and shellfish during each fishing operation. Some species and sizes are marketable and thus targeted, some others are unwanted bycatches most often discarded back in the sea. These unwanted catches may have a major ecological impact on the marine populations, and scientists, managers and stakeholders have long been in search of technical and political solutions to improve the selectivity of fishing and reduce unintended bycatches. However, the enforcement and the success of all these initiatives have globally remained limited so far, and the issues largely persist.

[1] Believed to be from John Shepherd but unverified

My scientific explorations over more than twenty years of research and advice in this field have been active and proactive, yielding more than 55 peer reviewed publications, a professorship in fisheries management, students' supervision and teaching, and constant interactions with society outside academia, including managers and decision-makers, stakeholders (fishers, environmental NGOs) and the wider public all over Europe.

In this introductory chapter, I first describe the various concepts and technical terms used throughout this document, and highlight the main stakes and management issues linked to them (section 1.1). Then I present a brief overview of the thread and timeline of the different phases of my scientific carrier (section 1.2) and how they followed the evolution of the EU Common Fishery Policy over the last two decades; This brings me also to presenting the key features of this fundamental, complex and controversial policy in Section 1.3. Finally, section 1.4 summarises my scientific production in relation to these concepts and terms, linking publications with various research themes. The actual synthesis of the results obtained and knowledge learned for three of these themes then follows in the subsequent chapters.

Eventhough I have also worked in collaboration and on shared publications on several EU sea basins, including in the Mediterranean Sea, the vast majority of my studies have focused on demersal fisheries from the Greater North Sea area (from the English Channel to the Kattegat, Figure 1.1), and most figures and examples presented in this thesis are from that area.

One can though argue that there are many common technical and political features with other EU regions of interest for the French fisheries, not least in the North and South Western Waters (NWW and SWW), and many of the statements here apply equally to these other Atlantic regions, with some nuances.

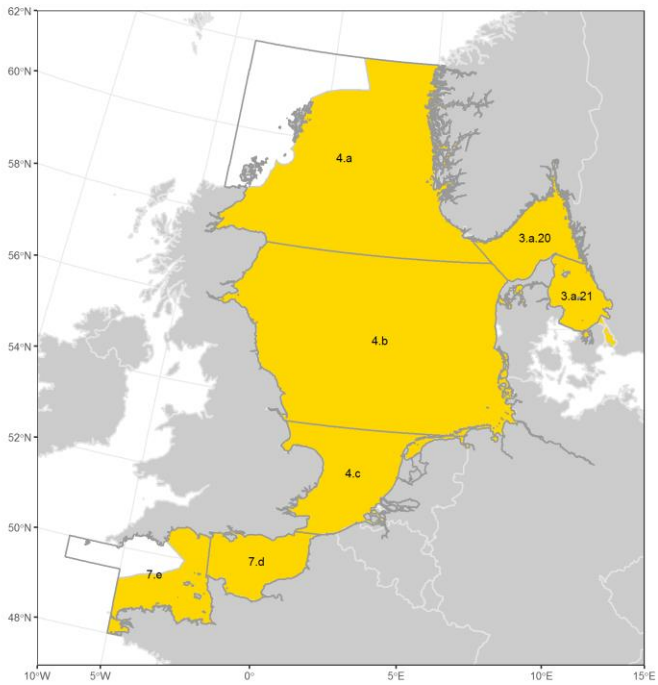



*Figure 1.1. The Greater North Sea ecoregion (in yellow) as defined by ICES. The relevant ICES statistical areas are shown. Source:*(ICES, 2019).

## 1.1 Definition of the key concepts used in this document, and main issues linked to them

### 1.1.1 Target species, bycatch, discards

The United Nations Food and Agricultural Organization's (FAO) Fisheries Glossary[2] gives a standard definition for target species: "*Target species - Those species that are primarily sought by the fishermen in a particular fishery. The subject of directed fishing effort in a fishery. There may be primary as well as secondary target species*". It makes indeed intuitive sense that some species and sizes are more marketable than others. In addition to the price value alone (which can itself vary according to season, area, world supply or consumer preferences), regulations contribute also to differences in the commercial interest in a species rather than another one. This is particularly true for fisheries regulated by Total Allowable Catches (TACs) and quotas, where some countries or some individual fishers within a country may not have legal authorisation to land and sell species for which they have no fishing rights or for which the quota is already exhausted.

It is however usually not straightforward to select and sort out the valuable part of the catch when the gear is in the water. Non-selective fisheries result in the mixed catch being hauled on the deck of the fishing vessels, including the component of the catch that is less desirable. The FAO Glossary describes thus by-catch as "*the part of a catch of a fishing unit taken incidentally in addition to the target species towards which fishing effort is directed. Some or all of it may be returned to the sea as discards, usually dead or dying*." Discards are accordingly defined as "*the proportion of the total organic material of animal origin in the catch, which is thrown away or dumped at sea, for whatever reason. It does not include plant material and post- harvest waste such as offal*".

As noted in these definitions, by-catch and discards may be dead or alive, depending on the severity of any sustained injury and stress suffered by being caught and discarded (Davis, 2002).

Globally, it has been estimated that between 7 and 10 million tonnes of commercial fisheries catches are discarded annually (Kelleher, 2005; Zeller et al., 2018). In Europe, the North-East Atlantic and North Sea have been identified as "discard hotspots" (Guillen et al., 2018), with a number of discard-intensive fisheries operating in the area (beam trawls and bottom trawls), especially for benthic species (Figure 1.2).

[2] http://www.fao.org/faoterm/collection/fisheries/en

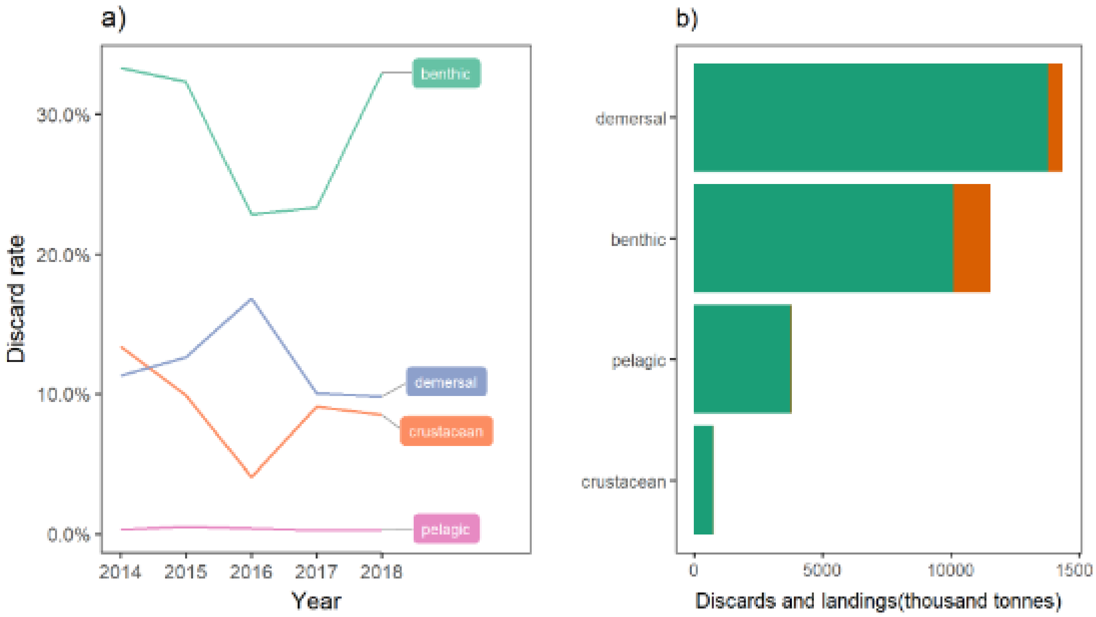



*Figure 1.2. Assessed stocks in the Greater North Sea. Left panel (a): Discard rates in 2014–2018 by fish category, shown as percentages (%) of the total annual catch in that category. Right panel (b): Landings (green) and discards (orange) in 2018 by fish category (in thousand tonnes) of those stocks with recorded discards. Source Figure 13 in* (ICES, 2019).

There are great ecological issues associated with discarding. Nevertheless, the link between discards and sustainability remains complex. Some stocks experimenting high discards levels can be sustainability exploited, the most emblematic example of this being North Sea plaice, which has been fished at Fmsy for many years in spite of discards rates among the highest in the world[3]. Conversely, low discards rate do not necessarily mean sustainable fishing. In reality, the key threat to sustainability is not exactly discarding per se, but whether discarding adds or not an unaccounted and unregulated mortality component above Fmsy, i.e. if the total sum of dead fish (landed + dead discards) exceeds what corresponds to levels delivering maximum sustainable yield (MSY). For example, in the case of North Sea plaice, discards mainly comprise small fish in rather constant proportions, which are accounted for in the setting of the annual TAC. At contrary, discards comprising large legal sized fish that cannot be landed by lack of fishing rights or low quotas may maintain high levels of total mortality, not in line with $F_{MSY}$.

### 1.1.2 Mixed fisheries and technical interactions

The concept of mixed fisheries arise from the process described above, where several species are caught together but some are targeted while other are bycatch. If these species have different dynamics, sensitivity to fishing and biological status, then management becomes a difficult multi-dimensional trade-off between exploitation and conservation.

[3] http://ices.dk/sites/pub/Publication%20Reports/Advice/2020/2020/ple.27.420.pdf

*Figure 1.3 A mixed fisheries haul in the English Channel. Picture Courtesy A. Balazuc (2015)*

The characterization and quantification of mixed fisheries began in the early nineties in France, with the seminal work of (Laurec et al., 1991). It builds from a need to identify an intermediate medium layer to describe the dynamics of fishing, in between considering all fishing pooled together without accounting for their diversity on the one hand, and monitoring each vessel individually on the other hand.

The terminology has evolved over time, and in 2008, the European Data Collection Framework (EC, 2008a) defined two concepts to characterize fishing activities that we will use here.

• A fleet (or fleet segment) is a group of vessels with the same length class and same predominant fishing gear during the year. Vessels may have different fishing activities over a year, but might be classified in only one fleet segment.

• A métier is a groups of fishing operations targeting similar species or assemblage of species, using similar gears during the same period of the year and/or within the same areas and which are characterized by a same exploitation pattern [i.e. the species composition and size distribution of the catches taken by any vessel using that métier will be similar, (Deporte et al., 2012)].

As such, the fleet describes the vessels while the métier(s) describes the fishing activity(ies) in which the fleet engages. Fleets are linked to métiers through the fleets' effort patterns, and métiers are linked to species/stocks through the catchability pattern (Figure 1).

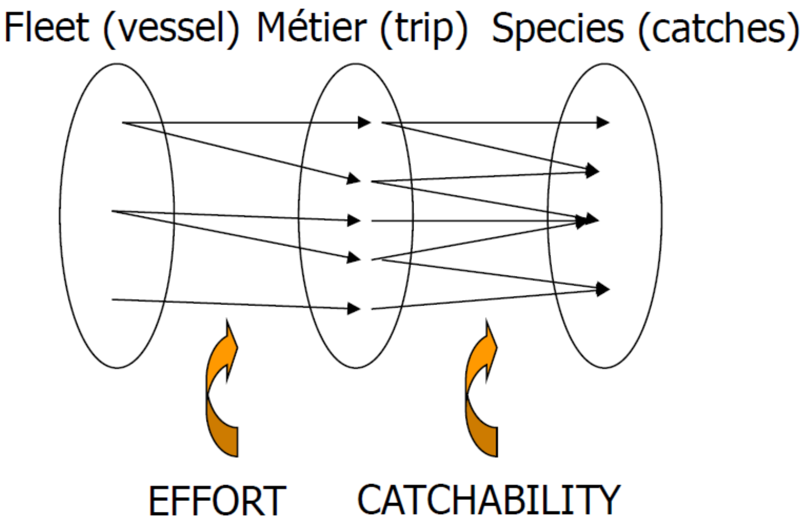



*Figure 1.4. Conceptual diagram of the links between fleets, métiers and species in a mixed-fishery context (Source (Ulrich et al., 2012, #7).*

While these concepts are qualitatively simple and intuitively meaningful, there are many issues linked with their operational use in management. By far the main issue is the basic challenge of definition and categorisation, requiring some choices to be made in the datasets used, the scale and criteria of aggregation, and the aggregation methodology in order to quantify the size (e.g. number of vessels) and impact (e.g. total catches) of each group; and there is no unique and simple way to achieve this.

This issue being my first key area of research over the years, including in my PhD, the state of knowledge on this topic is described in Chapter 2 of this HDR.

### 1.1.3 Selectivity

The FAO Glossary describes selectivity as the "*Ability to target and capture fish by size and species during harvesting operations, allowing by-catch of juvenile fish and non-target species to escape unharmed. In stock assessment, conventionally expressed as a relationship between retention and size (or age) with no reference to survival after escapement*."

One of the most common ways to reduce discarding is to improve gear selectivity (Broadhurst et al., 2006) by either exploiting the various behavioural and morphological differences between species or sorting the catch mechanically based on size. As such, prescribing the use of selective gears has long been seen as an obvious management measure to promote the sustainable exploitation of commercial fisheries. However, the mere evidence of the sustained existence of discards worldwide shows that this management action has not been successful overall, for several reasons.

The first reason is technical. Even with the best intentions in the world, the diversity of size, shape and swimming/herding behaviour of demersal marine species, coupled with the co-occurrence of their habitats (which can in itself vary a lot over time and space), makes it technically impossible to perfectly select what is retained by a fishing net or trawl. To be more precise, it would actually be technically possible to avoid bycatches in the sense that huge meshes would allow any species to escape through, but this would not have any economic sense of course. So an economically profitable fishery uses a mesh size that is a trade-off between catching what is to be sold and escaping what is to be avoided. When the valuable targeted species are either smaller (like red mullet), thinner (like sole) or spinier (like Norway lobster) than the overexploited or protected bycatch species that should be avoided, there are usual no “silver bullet”, i.e. simple technical design of the gear or of a selective device that can exactly retain only the valuable part of the catch. The need to decouple catches of different species and/or sizes is thus challenging and often results in compromising on some aspects of the selective performance of the gear (Figure 1.5).

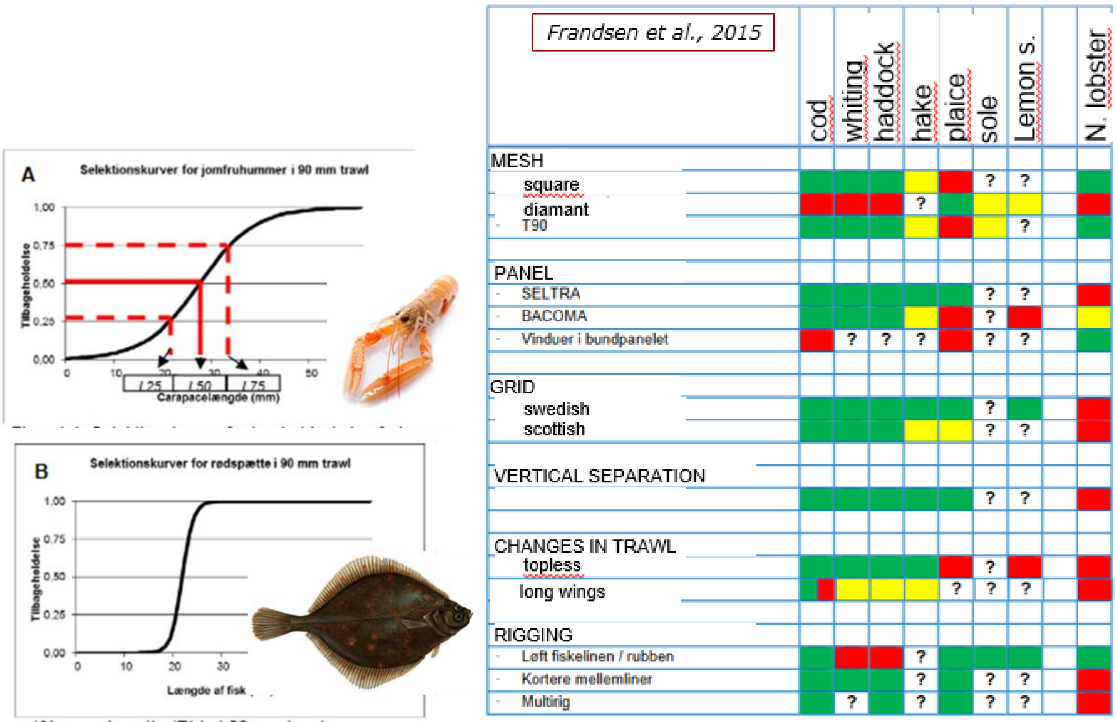



*Figure 1.5. Left : Examples of different Selection curve (% retained in gear per animal length class) in a 90 mm trawl, a wide curve for Norway lobster (top) and a narrow curve for plaice (bottom). Right : List of the potential unwanted species and the gear design and selective devices that can influence their selection, Danish fisheries. The gears that give possibility to reduce catches are shown in green. Gears that either do not influence the selectivity or rather increase the catches of the species are marked in red. Gears for which quantitative information is missing but would be expected to have some positive effects are marked in yellow. From Frandsen, 2015 (original figure in Danish).*

The second reason is economic and socio-political. A very clear pattern is that selective gears are in far most cases not taken up voluntarily by fishers. In the recent years, increased research has been dedicated into understanding fishers’ behaviour, incentives and norms (see also Chapter 3), and it is now better understood why and how the current regulatory, control and economic frames do not create enough positive incentives to fish selectively. To explain this briefly: (i) On the top-down aspect, the EU regulation on technical measures in place for many years until its reform in 2019 have typically enacted authorised gears for an entire region, with little option to account for the complex differences occurring across and within the fisheries. Only one or few gears have been prescribed for each fishery and region, though with extremely detailed technical specifications of the gears allowed to be deployed. This lets very little room for adapting to individual situations, where different fishers have different reasons to target one or another species, typically depending on e.g. market price, season and on their individual quotas' portfolio (Eliasen et al., 2019, #21). (ii) On the bottom-up aspect, the fishers' objective, once at sea when expenses are engaged, is naturally to maximise the market value of his catch, an incentive that is further reinforced by the usual system of the crew's pay share (the crew receive a fixed proportion of the trip's revenue). For many species, the selection curve is not as jack-knife edged as plaice in Figure 1.5 above, but is flatter, implying that increasing mesh size often imply losing a part of valuable (i.e. above the minimum legal size, now called Minimum Conservation Reference Size MCRS) fish. This is often felt inherently "un-natural" for a fisher even if that proportion is small, and even more when the overall profitability of the activity is limited and every fish counts, as has long been the case in European fisheries (STECF, 2019). As such, (some/most) fishers might want to compensate for the short term commercial loss through various "adjustments", de facto nullifying the expected selectivity effect of gears (Krag et al., 2016).

The consequence of these two aspects means that fishers' individual incentives are usually not well aligned with the societal conservation goals, and selectivity trials, even when conducted in collaborative projects with the fishing industry, do often not lead to obvious selectivity improvements at fishery level. A key issue for the future is thus to move away from "tunnel vision" (Degnbol et al., 2006) and try to better align top-down and bottom-up incentives in a more "win-win" approach promoting responsible fishing (Eliasen et al., 2019; Feekings et al., 2019, #21-22). These aspects are discussed in Chapter 4 of this HDR.

## 1.2 Evolution of my carrier thread in relation with the Common Fisheries Policy.

Almost only financed on collaborative EU research projects in the frame of the successive research framework programs FPs (5th, 6th, 7th and H2020 FPs), my scientific carrier and my research focus have followed the evolution of the Common Fishery Policy (CFP) in Europe, which started in 1982 and has been reformed every ten years since then (see section 1.3 below). My own carrier started though only in 1997, and can be split into three phases.

The first phase, from 1997 to 2001, is my « Junior period », PhD student (in AgroCampus Rennes, France) and postdoc (in DTU Aqua, Technical University of Denmark, Copenhagen region). At that time the CFP was still not so different from its first 15 years of existence, being essentially focused on managing the sharing of TACs between fishing nations' quotas rather than on securing the conservation of resources and sustainable fisheries (Penas Lado, 2016).

In 2002 a new CFP was launched (EU, 2002), with much more ambitious objectives in terms of responsible management, long-term planning, international collaboration, and involvement of stakeholders; that year I also entered the second phase of my carrier. I got permanently hired at DTU Aqua, first as scientist, then as a senior scientist in 2005. There I matured my own research on mixed fisheries management, and shared it directly with stakeholders and policy makers through extensive activities of expertise (not least within ICES working groups) and advice to national and European authorities. That second period lasted until 2013.

Finally, after 2014 the CFP took again another ambitious turn with the extensive 2013 reform (EU, 2013), focusing among others on implementing regional mixed fisheries management and addressing the bycatch and selectivity issues through the banning of the discarding practice (the landing obligation, LO, see below); this is exactly the time where my carrier also took another ambitious turn and entered a third phase. I got appointed as full professor in fisheries management at DTU in late 2014, and led a successful proposal on a H2020 call dedicated to supporting the implementation of the LO during its entire period of gradual implementation (H2020 DiscardLess[4], 2015-2019); That proposal received the highest possible mark, 15/15, when evaluated by the EU. Meanwhile I supervised a postdoc and a PhD student. At the same time, I also took responsibilities in the EU Scientific, Technical and Economic Committee for Fisheries (the STECF)[5], the scientific advisory committee of the European Commission. I got first appointed as a member in 2012, and then became its chairperson in 2016 (and re-elected for a second chair mandate in 2019). Being simultaneously the international coordinator of a large-scale research project on fisheries management, while witnessing at first hand the issues and challenges daily faced by the EU and by Member States in their management decisions, widened greatly my vision and understanding of the EU socio-ecological fisheries system. It also opened many new questions on how to achieve sustainable mixed fisheries and reduce unwanted catches.

This scientific, political and human endeavour over two decades in France and Denmark brought me in contact with many people over many countries. I learnt a lot and gave back the best I had… which led me to the immense honour of receiving the ICES Outstanding Achievement Award in September 2020[6], one of the highest recognition one can receive in our field.

Many of the questions I worked on are, however, still largely unanswered today… But for the first time my path has now moved slightly away from the CFP, as I operated a major carrier shift in 2019 and started as Deputy Head of Science at Ifremer, France, with different types of responsibilities. As a consequence, this HDR thesis will not describe my own future research plans as such, but rather my reflexions on the future needs for fisheries management and fisheries research in our challenging future.

## 1.3 The Common Fishery Policy

This parallel track between my scientific carrier and the Common Fishery Policy obliges me to provide a few more words and details about this fundamental, complex and controversial policy, and how it is shaping the evolution of European fisheries.

Although fishing represents only a very small part of EU economy (less than 1% of EU gross domestic product GDP), the conservation of marine biological resources under the CFP is one of the few domains of exclusive competence of the EU, together with five other domains of much larger economic weight[7]. The CFP is one of the most integrated policies of the European Union. Its political importance reaches far beyond the economic importance of the fishing sector in Europe, as illustrated by the prominent place given to fisheries in the Brexit story-telling and negotiations.

### 1.3.1 Origin and historic perspective

It is vital to remember the past to understand the present, since most of today's problems in EU fisheries management have precedents long back in history. An excellent reference for understanding the origin, evolution, achievements and challenges of this comprehensive policy in quest for sustainability is the book by (Penas Lado, 2016), and the paragraphs below build largely on this source.

The political focus on fisheries was very limited in the EU founding Member States, and fishing was largely unconstrained in post World War II years, when supplying food to EU

---

[4] http://www.discardless.eu

[5] https://stecf.jrc.ec.europa.eu/

[6] https://www.ices.dk/news-and-events/newsarchive/news/Pages/OutstandingAchiement2020.aspx

[7] customs union, the establishing of competition rules necessary for the functioning of the internal market, monetary policy for euro area countries, common commercial policy, and conclusion of international agreements under certain conditions; https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=LEGISSUM%3Aai0020

populations was the priority. The core business of the CFP, the conservation policy, emerged around the same time as the United Nations Convention on the Law of the Sea (UNCLOS).  its origin can be more precisely traced back to two fundamental events for European fisheries: the first enlargement of the Union in 1973 with the accession of three large fishing nations, United Kingdom, Denmark and Ireland; and the declaration of Exclusive Fisheries Zones (EEZs) by Atlantic and North Sea Member States in 1977, after the so-called "cod wars" when UK lost access to Icelandic fishing grounds.

The opposite driving forces within each nation to both protect their own fishing grounds from foreign fleets on the one hand, and secure their historical fishing rights in other nations' fishing grounds on the other hand, led to complicated political processes. It is only in 1982, after six long years of negotiations, that the first conservation regulations were established and that the first CFP was born. Clearly though, this first policy reflected much more the need to regulate the shared access to the common fishery resources than to ensure their sustainable harvest.

Since then, the basic deals leading to the adoption of this first policy have remained remarkably stable. In particular, the regime applicable to the 12 miles of the territorial sea and the allocation of fishing rights among Member States through relative stability still apply today, with largely unchanged distribution keys sharing the TACs and quotas between EU Member States. Acknowledging though that these distribution keys agreed in the 80s were to some extent more generous for the existing EU Member States than for the new states entering the EU at that time (and notwithstanding the often unequal quota sharing process that also takes place within each Member State (Carpenter & Kleinjans, 2017)); and keeping in mind the changes in species distribution and productivity that have taken place since the 80s (and which are accelerating now with climate change), it is easy to figure out that the fishing rights owned today by every EU fishing fleet for every fish stock do not necessarily match well with the availability and abundance of that stock on the fishing grounds of the fleet. In short, for many fish stocks, some fleets own enough, or even too much, quotas to cover their own catches, while other fleets have too little quota, even for some abundant stocks like North Sea plaice (Figure 1.6). Some swaps occur but for many stocks they are not sufficient and effective enough to cover all gaps. Catches without fishing rights cannot be sold and is thus thrown away. This mismatch in fishing rights is thus one of the key drivers of the large amounts of discarding observed in European fisheries in comparison with other mixed fisheries worldwide.


*Figure 1.6. Quota surplus/deficit per Member State for North Sea plaice compared to catches in 2015. Source :* (NSAC, 2017a).

The key message here, is that the historical CFP and its rigid distribution rights across many Member States is thus both a main factor leading to the inception of the EU landing obligation (discard ban) in 2013, and a main barrier against solving the discarding issue, as will be discussed in Chapter 4.

Before we jump to today's CFP and the landing obligation, a few more historical perspectives on the period between 1982 and 2013 are though useful to understand where we stand today, in particular concerning the conservation of fisheries resources.

### 1.3.2 The slow emergence of conservation priorities.

The CFP was reformed once in 1992, though with little changes compared to 1982. The main noticeable event in that period was maybe the non-accession of Norway in the EU in 1995, largely because of failed fisheries negotiations and the impossibility for Norway to refuse access to its productive fishing grounds to other EU fleets if becoming an EU Member. These two decades of CFP are characterised as a long period of chronic overfishing, with exploitation levels high above those providing the Maximum Sustainable Yield (Fmsy) and low abundance levels for most exploited stocks, as shown in the historical overviews published by the International Council for the Exploration of the Sea (ICES) (Figure 1.7).

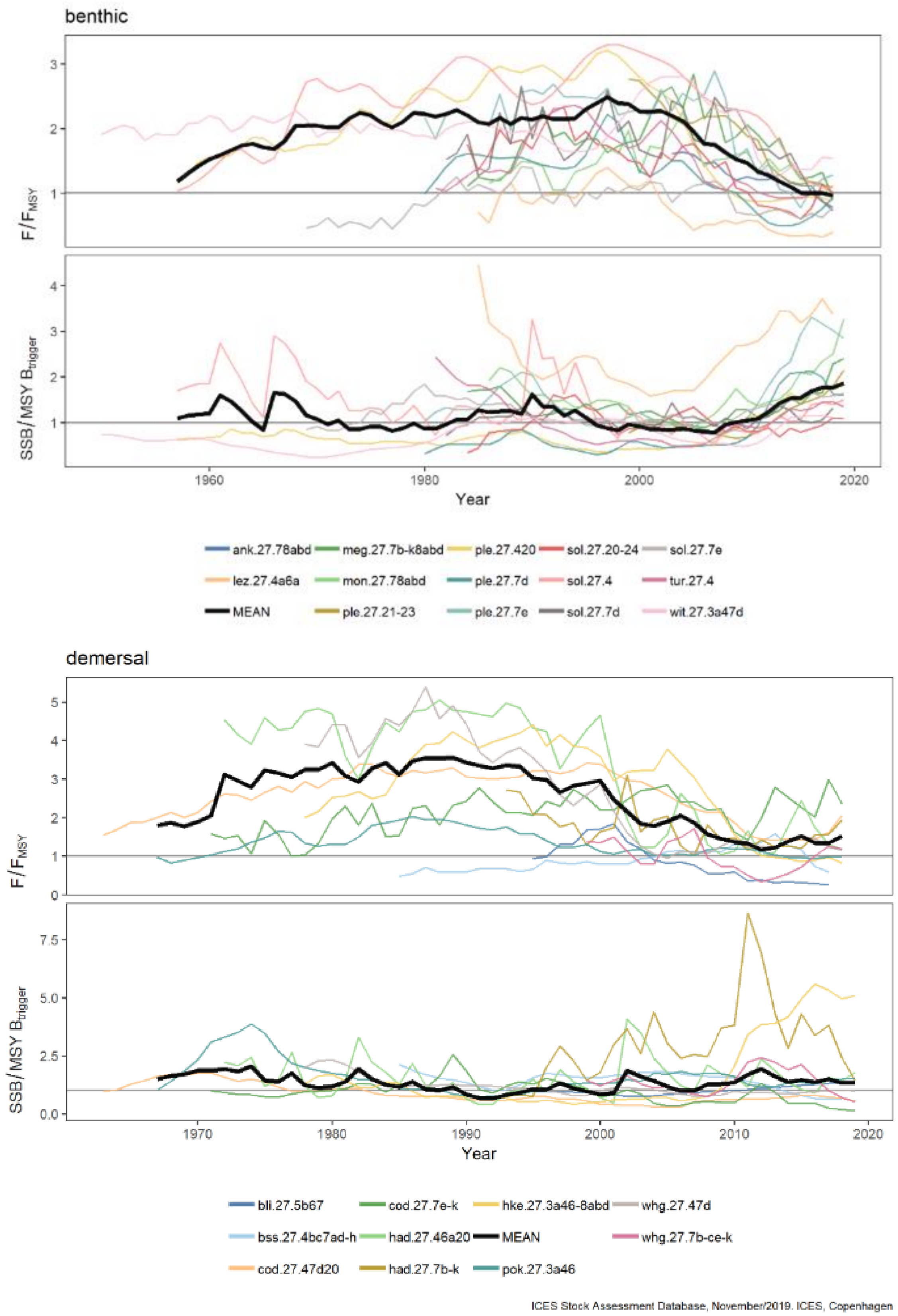



*Figure 1.7. Temporal trends in F/FMSY and SSB/MSY Btrigger for North Sea benthic and demersal stocks in the Greater North Sea area. Only stocks with defined MSY reference points are considered. Source : Figure 18 in* (ICES, 2019)*. For full stock names, see Table A1 in the Annex of this document.*

The period saw only a slow evolution of the number and role of the TACs. They were still only used then as a tool for the allocation of fishing rights, and thus also as a mean of exclusion of new Members like Spain and Portugal in 1986; but they were not used for conservation, as TACs in this period were usually set substantially higher than recommended by scientists during long nights of "horse trading" negotiations behind the closed doors of the annual EU Council of fisheries Ministers in December of each year (Carpenter et al., 2016).

Among other historical problems inherited from this early period, one can also mention the obvious lack of consistency of the conservation policy with the other main pillars of the CFP, namely the fleet policy and the structural and market policies. As such, on one hand the CFP invested in support and subsidies to sustain and modernise the EU fleet, and on the other hand it used public money for decreasing fleet overcapacity through expensive, and largely ineffective, decommissioning schemes.

It is only in the 2002 reform (EC, 2002) that a major change in focus took place. Awareness increased in face of the emerging evidence on the poor status of EU fish stocks, and for the first time the notion of "sustainability" appeared as a fundamental, albeit vaguely defined, objective. Among concrete actions foreseen in this new policy was (i) the first commitments to long-term management plans instead of the only short-term year-on-year management views, (ii) a ban on vessel construction subsidies (in the frame of the World Trade Organisation agreements), and (iii) the first initiatives to increase stakeholders' involvement and fisheries science partnerships through, among others, the creation of the consultative Regional Advisory Councils (RACs). While visible progresses were slow to emerge at the beginning of the period, it is nonetheless retrospectively clear from the Figure 1.7 above that the early 2000s mark the end of an era of largely ineffective conservation policy. After this date, the reduction in fishing levels framed in, among others, the successive "EU Cod plans" (EC, 2004, 2008b) started to show positive results.

One may also mention that as earlier, the successive enlargements of the EU towards the Baltic, Mediterranean and Black Sea riparian states translated into new policy needs and extended regulation coverage. Considering the differences in the extent and effectiveness of the level of regulations, enforcement, control and international collaboration existing in the new Member States at the time of their accession, it is easy to figure out the increasing challenges to agree on and implement EU-wide fisheries management objectives.

Reformed again a decade later (this time in co-decision with the European Parliament following the 2009 Lisbon Treaty), the 2013 CFP (EU, 2013) reflects an even larger step ahead in ecological awareness and conservation ambition, with the inclusion of three major elements:

- The introduction of a fully defined and quantifiable exploitation objective, the Maximum Sustainable Yield (MSY), acting that the sustainability of fish stocks is the priority objective;
- The landing obligation (LO) aiming to address the high amounts of discards in EU demersal fisheries
- The regionalisation, aiming to decentralise some decision power to EU Member States through the possibility for regional groups of Member States to propose management decisions through delegated acts.

However, as repeatedly pointed out by Penas Lado (2016), because of the diversity of situations across sea basins and Member States, the CFP is a policy where the basic political agreements leading to its establishment 40 years ago are extremely difficult to change. As a result, the CFP (and its side-policies such as the technical measures regulation, control regulation, data collection regulation etc) is growing into a very complex piece of legislation, where new layers of objectives and hole-fillings are added to –sometimes obviously outdated- historical “Pandora boxes” agreements that no one dares changing. This is very well illustrated in this simple figure by (Pastoors, 2014), who showed an exponential growth in the number of words included in the successive CFP reforms (Figure 1.8)! As a result, and as we will see throughout this HDR thesis, it can be challenging to identify workable solutions for the practical implementation of the objectives.

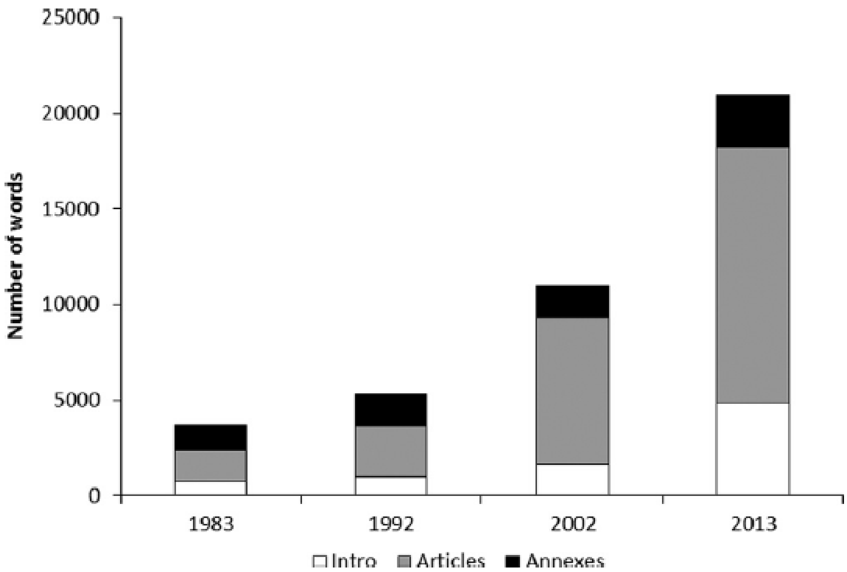



*Figure 1.8 Word-count of Common Fisheries Policy basic regulations in 1983, 1992, 2002 and 2013 (final compromise text) separated into introductions, articles and annexes. Source: Figure 1 in Pastoors (2014).*

The 2013 landing obligation is emblematic of this difficult trade-off between setting common ambitions and level playing field on the one hand, and acknowledging the reality of the diversity of situations across the numerous sea basins, Member States, fleets and fish stocks on the other hand. Having been the main frame of my research developments in my third carrier phase, this policy is briefly presented in the next paragraph.

### 1.3.3 The 2013 landing Obligation, and the issue of choke species

The landing obligation, the requirement to land all catches of certain fish species, was introduced as part of the EU’s new Common Fisheries Policy (CFP) in 2014 (Article 15 in EU, 2013). However, the history of the EU discard policy started several years earlier, when the Commission first published in March 2007 a communication recognising the serious problem of discarding in European fisheries (Borges, 2015).

By many ways, the evolution of the EU discard policy has been driven by the conflictual situation experienced in the North Sea demersal fisheries. There has long been a striking contrast between the situation in the EU waters, where discards rates have historically been estimated to be among the highest in the world (Kelleher, 2005), and the situation in the Norwegian waters where a discard ban had been in place since 1987 (Diamond & Beukers-Stewart, 2011).

An incident involving a UK trawler discarding loads of valuable fish at the border of the North Sea's Norwegian waters in 2008 generated public pressure to end discarding. Later in 2010, it is again in the North Sea that the public campaign of the UK celebrity chef known as "Hugh's Fish Fight" prompted a very strong public reaction. The campaign mainly highlighted just one cause of discards, the quotas, blaming the EU management system and its perceived draconian and ineffective measures. Ultimately, the EU landing obligation thus emerged out of this strong emotional context, but after having been in question for a long time and after many tergiversations (Figure 1.9).

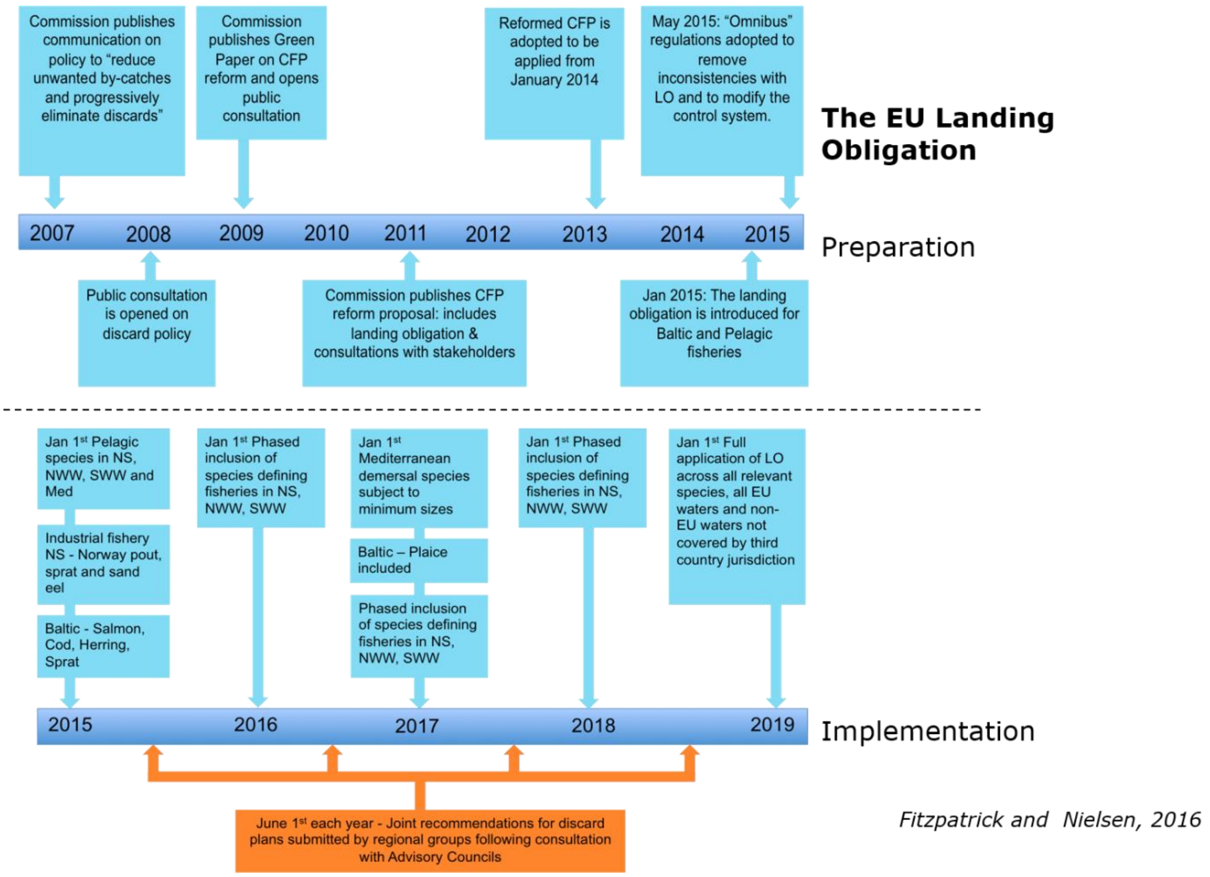



*Figure 1.9. The Timeline of the Landing Obligation. Source:(Fitzpatrick & Nielsen, 2016)*

The article 15 is a long, complex and detailed article in the 2013 CFP text. Where many other articles describes only the overall objectives, letting implementation details to be agreed later during the regionalisation process (as is e.g. the case for the regional multiannual plans), the LO prescribes already all the conditionalities, including species, fleets, calendar of implementation and provisions for exemptions (demonstrated high survival of the species and *de minimis* exemption if selectivity is shown to be very difficult to improve or sorting costs are considered disproportionate – though with describing how « high », « very difficult » and « disproportionate » should be measured). The obvious aim was to be directly legally binding and not let room to much negotiation that would fade of objectives.

The landing obligation represents probably the most important paradigm shift in the history of the Common Fishery Policy, shifting its focus from landed catches to all catches, including discards. When discarding is allowed, fishing is driven by maximising the value of the fraction of the catch that can be sold. When discarding is banned, fishing becomes also driven by the need to minimise the quantity of the fraction of the catch that cannot be sold. This means that fishers become accountable for their entire catches of regulated stocks, and not of their landings only.

Changing this fundamental approach to the way fishers operate their business requires a major change in mindset, which can only take place if fishers supports its legitimacy, which is not the case and opposition has been fierce. Additionally, the transition costs of this paradigm shift are real. Discarding is an invisible externality cost for fishers and society, which becomes internalised when discarding is banned. Even in a situation where fishers would not be limited in their access to fishing quotas, a landing obligation makes fishing less cost-effective in the short-term, both by increasing the costs (more trips back to harbour; more work for the crew; more infrastructures needed) and reducing the value of the catch (less valuable species and sizes; lower quality).

Furthermore, this situation only worsens when limiting quotas add "choke issues" to this dire picture. A "choke" species is a species for which the available quota is exhausted (long) before the quotas are exhausted of (some of) the other species that are caught together in a (mixed) fishery (Zimmermann et al., 2015). Choke species incarnate the core difficulty to solve the discarding issue in the context of European shared stocks. The fishers with access to too little quota will not be able to balance this by discarding overquota catches, but would be required to stop fishing or engage in a different type of fishery when their most limiting quota is exhausted. To avoid such early closures without addressing the fundamental inequity of access to quota among fishers, other mechanisms must thus be established, that would reduce unwanted catches without jeopardising the viability of the fishing sector.

As a consequence of these two aspects (reduced profitability and choke issues), banning discards is a difficult measure. A number of countries have already implemented discard bans, including Canada, New Zealand, Norway, Iceland and Chile, and experiences with these countries have been reviewed (Karp et al., 2019). All cases show that the implementation of discard bans requires high levels of at-sea monitoring and effective control, and/or strong incentives to fish more selectively, neither of which applied in most cases examined. They also show that progresses were slow, with the Iceland taking 30 years (a fishers' generation time) to move into a mindset of full utilisation of all catches.

It is obvious that these inherent difficulties also apply in full strength to the European demersal fisheries. Since the early steps of establishing a knowledge baseline and defining roles and responsibilities in the new frame of the regionalised CFP in 2014 (Quirijns & Pastoors, 2014), some things have already changed in the governance of the European fisheries, and considerable research efforts have been dedicated in recent years to address the many questions surrounding the LO implementation; nevertheless, no effects on actual discards rates and fishing practices have yet been observed (cf Figure 1.2 above). This will be further discussed in Chapter 4.

## 1.4 Summary of my research topics and publications

As explained in section 1.2 above, the most representative keyword of my scientific focus from past to present is thus *mixed fisheries management*. The concept of mixed fisheries represents a convenient medium layer between fully aggregated stock-based approaches disregarding the differences in impact between different types of fisheries in the one hand, and fully disaggregated individual-based approaches where every single fishing boat is modelled as an individual agent on the other hand. During my first and second carrier phases (1997-2013) I investigated the concept further and worked towards making it operational in a management advice context. This translated into numerous studies and publications, aiming to:

i) developing robust statistical methods for identifying and characterizing these homogeneous groups of métiers and fleets, and for assigning individual trips and vessels into them (#12, 16, 40, 42, 47),
ii) modelling the differences in dynamics between the various stocks and fleets involved in the mixed fisheries (#15, 48, 49, 52, 54),
iii) developing flexible bioeconomic modelling platforms for the simulation of management strategies, able to deal with many stocks and many fishing units (#8, 11, 13, 43, 44, 50, 51),
iv) framing and conceptualising the usual mixed-fisheries management issues typically encountered in demersal fisheries, and evaluate them through simulation (#8, 10, 14, 46, 49, 54) and
v) integrating all the steps above into an operational process for delivering timely and salient advice on mixed-fisheries MSY, and learning how to best convey these concepts to the outside world (managers and stakeholders) (#9, 39, 45)

Less rewarded by scientific publications but just as important for achieving this operationalization, I performed a tremendous work over the end of the second phase to improve the quality, availability, legitimacy and transparency of the international data involved in this process, through ambitious and dedicated effort in ICES and STECF. In this aim I took a leading role (chairmanship and main developer) in key Experts Working Groups in order to steer the advisory process towards the vision I had for it.

This combination of simultaneous improvement in mixed fisheries data, models and MSY framework resulted in a new type of advice (mixed-fisheries advice) being fully integrated in the official ICES advice in 2012, and routinely updated since. In 2019, this mixed-fisheries advice was further developed with new elements added, to form the now called « Fisheries overviews » (ICES, 2019)[8].

Summarizing this long-standing and innovative work, my learnings and my thoughts on the overall topic of mixed-fisheries management can be read in the key synthesis publication (#7), which balances the challenges and opportunities of these mixed-fisheries approaches for operational management and modelling. These are the topics of the chapters 2 and 3 of this HDR.

Beyond these studies above which are the core outcomes of my own research, I also collaborated closely with other scientists (not least during my post-doc and co-supervision of a PhD student when I was young researcher) on other aspects of fisheries science. In particular, I contributed to the better understanding of which differences exist among individual vessels and trips within homogeneous fleets and métiers groups, and how this influences the relationship between fishing effort and fishing mortality (#41, 46, 53). In parallel, I also pursued biological investigations on the stock whose assessment I was responsible for in many years, namely the stock of plaice in Kattegat-Skagerrak. I demonstrated the evidence of merging populations, ultimately leading to the lumping of this stock with the stock of plaice in the North Sea (#4, 6, 31).

[8] http://ices.dk/advice/advisory-process/Pages/fisheries-overviews.aspx

During the third phase (2014-2019), my new responsibilities as international coordinator of H2020 DiscardLess and Chair of EU STECF, as well as my increased teaching and supervision duties widened the multidisciplinary dimension of my publications, with the global aim to i) help understand the economic, biological and social drivers and impacts of the catching and discarding of unwanted sizes and species in the process of fishing, and ii) contribute to proposing options for discard reduction. This led to studies in different directions. On the one hand, I pursued the technical analyses and modelling of mixed fisheries, now also with a focus on the processes leading to the capture of unwanted size and species and the options to reduce them (#2, 18, 25, 28, 32, 37). On the other hand, I took a wider and more holistic turn, studying the mixed fisheries system as a whole with more of its human dimension, including aspects of governance, impact of regulations, social norms, incentives and control (#21, 22, 23, 30, 36). Of particular interest to mention are the live experiments on Fully Documented Fisheries (FDF) involving cameras onboard fishing vessels, conducted in Denmark between 2008 and 2019 to enhance responsible fishing, discard reduction and results-based management. I was lucky to lead the analysis of the outcomes of these experiments, describing encouraging changes in behaviour by the fishers participating to these voluntary trials (#5, 17, 24, 33, 34, 35). On this particular FDF topic, the supervision of, and collaboration with, the post-doc student Lars O. Mortensen and the master and then PhD student Kristian S. Plet-Hansen on this subject has been very successful, with 12 publications I co-authored with them. This is the subject of Chapter 4 of this HDR.

This activity culminated in the edition of an open access book on the European landing obligation, featuring 20 chapters summarising the main outcomes of H2020 DiscardLess. (Uhlmann et al., 2019, #27).

Finally, the three synthesis studies I wrote for the European Parliament in 2016, 2018 and 2019 (#1, 3 and 20) have been major milestones in bringing my thoughts together into a holistic and non-academic way, and contributed substantially to the completion of this HDR thesis.

## 1.5 Presentation of the following chapters of this HDR thesis

This first chapter has presented the global flow of development of my scientific carrier of research and advice, and the context in which it has taken place. In the following chapters, I chose to describe and summarise the key findings of three different topics that I have worked on successively:

- Chapter 2 deals with the scientific challenges in defining métiers and quantifying technical interactions [Main research topic in 2000-2010]
- Chapter 3 deals with a proposed framework for the MSY-based management of mixed fisheries [Main research topic in 2004-2017]
- Chapter 4 deals with the options and barriers to achieve the reduction of unwanted catches in the context of the landing obligation including specific insights on electronic monitoring and Fully Documented Fisheries [Main research topic in 2013-2019].

# 2 The scientific challenges in classifying and quantifying technical interactions

*This chapter is partly extracted, and modified as appropriate, from (Ulrich, 2018; Ulrich et al., 2012 #1,7)*

As introduced above in section 1.2, the idea of "fishery", "fleet" or "métiers" are concepts that one can qualitatively agree on, as it is obvious that different types of fishing activities performed by different types of fishing vessels using different types of gears will result in different types of impacts on the ecosystem and marine resources.

Nevertheless, issues arise when trying to quantitatively define what these activities really are, and to allocate fishing units to the various categories. It is not simply, as one may think, that things are not "clearly defined", it is more complicated than that. Many of the concepts we have to deal with in mixed fisheries are 'essentially contested concepts' (Gallie, 1956), meaning that their definition always depends on the speaker's interest in how it is defined (Wilson and Jacobsen, 2009). Fleets and métiers are only abstract aggregations of multiple individual fishing vessels and fishing operations operated by humans. As such, they are not natural entities that are pre-defined and for which is it easy and clear to know what and who belongs to which group.

Fleets and metiers must thus be defined artificially, and there are many ways by which fishing activities can be considered alike or different from each other. Because each vessel (and each trip, respectively) is unique in terms of catch rate, fishing type, profitability, incentives, etc., it is by nature difficult to get simple and meaningful averages and to identify key fishing patterns. Defining métiers has thus raised extensive debate in the scientific community and there has been a large body of literature produced over the last 30 years, trying to identify the best and most robust method(s) to classify fishing operation in homogeneous groups.

In short, three main issues arise when comparing fishing activities: 1) which dataset, 2) which comparison criteria to use, 3) which scale?

Here below we briefly recall the definitions of concepts and summarise the challenges linked to these two questions.

## 2.1 Which criteria to define fleets and metiers?

As first described by (Marchal, 2008), métiers can be defined according to either trip inputs (available records of the technical features of fishing trips, e.g. gear and mesh size used, fishing grounds visited, season etc) or trip outputs (empirical or statistical analyses of landings or catches composition in weight or in value, called "catch profiles"). Combined methods relate catch profiles (outputs) to fishing trip characteristics (inputs).

In the EU, both types of approaches have been used, for different purposes. Inputs-based definitions have been used in the effort management regimes in place during the period 2003-2008 (EC, 2004) and 2009-2016 (EC, 2008b; Kraak et al., 2013). Categories (métiers) for days at sea limits were defined in terms of gear type and cod-end mesh size combinations, known as e.g. for the North Sea, TR1, TR2, BT1, BT2, together with several additional possible "*Special conditions*". Inputs-based definitions are also used in the Annual Economic Report (AER, (STECF, 2019)), where fleet segments are defined according to vessel size and main gear, and these broad categories can include very different vessels and activities within a group.

Combined/output-based methods have been used in the EU Data Collection Framework (DCF,(EC, 2008a)) for the scientific sampling of biological data. Métiers have been defined according to a hierarchical structure using six nested levels, of which level 5 relates to the "Target assemblage" based on main species type (e.g. Demersal fish vs. Crustaceans or Cephalopods). For example, the main bottom trawl fishery will be coded OTB_DEF_>=120_0_0, which means "*Bottom trawl with Otter boards_targeting demersal fish assemblage_with mesh size in cod end above 120 mm_no selective panel in trawl_no selective device in codend*."

Substantial difficulties are however linked with both approaches (Ulrich et al., 2012, #7). Input information such as gear and area can link to very different types of fisheries, and mesh size is not always a good descriptor, even when it is accurately recorded. In the North Sea, a good example of this is given by the vessels targeting almost exclusively saithe, in comparison with the more mixed roundfish fisheries where saithe is caught together with e.g. cod, haddock and whiting, although the same gear and mesh size are recorded in the logbooks (TR1, bottom trawl with >= 100 mm codend meshsize). Similarly, bottom trawls with mesh size less than 100 mm (TR2) can target both Norway lobster or whiting. This lack of relationships between the recorded mesh size and the catch composition is demonstrated to be even more problematic in the Celtic Sea than in the North Sea (Moore et al., 2019).

Conversely, in the case of output-based methods, interpreting output information such as catch composition is hampered by a number of recurrent questions on the choice of data on which to apply the catch composition analyses, as described below.

## 2.2 Which data?

The first choice to be made when attempting to statistically define fleets and metiers based on catch composition is to select the dataset on which to perform the analyses. This choice is not trivial in itself. Notwithstanding the added difficulty that in the EU, several alternative fisheries datasets are available in different databases, the main questions to answer are:

- Which level of aggregation? Many public datasets[9] aggregate catches at the level of large areas (e.g. ICES subares, see Figure 1.1) and time periods (quarter). However, it is now widely acknowledged in the scientific community (cf (ICES, 2020a)) that analyses/algorithms used to define métiers should be run not even at the scale of the fishing trip, but ideally at the scale of the individual fishing operation (e.g. trawl haul), as fisher might engage in several métiers during a single trip by changing fishing grounds, gear or rigging. Using more aggregated level (trip, quarter, fleet...) will result in averaging different fishing practices and exploitation patterns (see e.g. (Plet-Hansen et al., 2020, #19).
- Should target species be defined on the basis of catch volume (thus privileging the most abundant species) or catch value (thus increasing the importance of high-valued but low-volume species)?
- Are discards data available? Analyses based on compositions are sensitive to discard practices. The perception of "targeting" behaviour can vary a lot if looking at landings compositions rather than catch composition, especially if some species caught don't have market value, if fleets have quotas restrictions or if the gear is not selective enough and catches a lot of undersized target species. Ultimately, the species proportions in landings before the landing obligation should expectedly be quite different from the species proportions in landings after the landing obligation is enforced.

[9] See for example the datasets available from the STECF at https://stecf.jrc.ec.europa.eu/data-dissemination

- How many years of data to retain, and how to account for natural fluctuations in fishing strategies and catch patterns? In addition, climate change is expected to affect species distribution, although in a not homogeneous way (Northern Hake or bluefin tuna are good examples). These changes will then alter catches and landings profiles and challenge the perception gained from historic observations.

## 2.3 Which scale?

The question of scale is just as difficult to answer. In reality, each vessel (and each trip or haul, respectively) is unique in terms of catch rate, fishing type, profitability, incentives, fishing strategies etc. Ultimately, two fishers from the same harbour fishing in the same way may have quite different catch composition. And two consecutive hauls from the same vessel can yield very different outcomes (Mortensen et al., 2018, #30).

As such, fisheries are not concrete entities but only abstract aggregations of unique events, and their average patterns will be dependent of the chosen scale of aggregation. Like a fractal or a snowflake, differences will appear when zooming in within a fishery, with catch composition varying according to e.g. season, fishing place, home harbour, vessel size, skipper etc. (Figure 2.1). Defining fisheries requires thus a trade-off to be made between the number of fisheries units defined and their internal consistency and homogeneity.

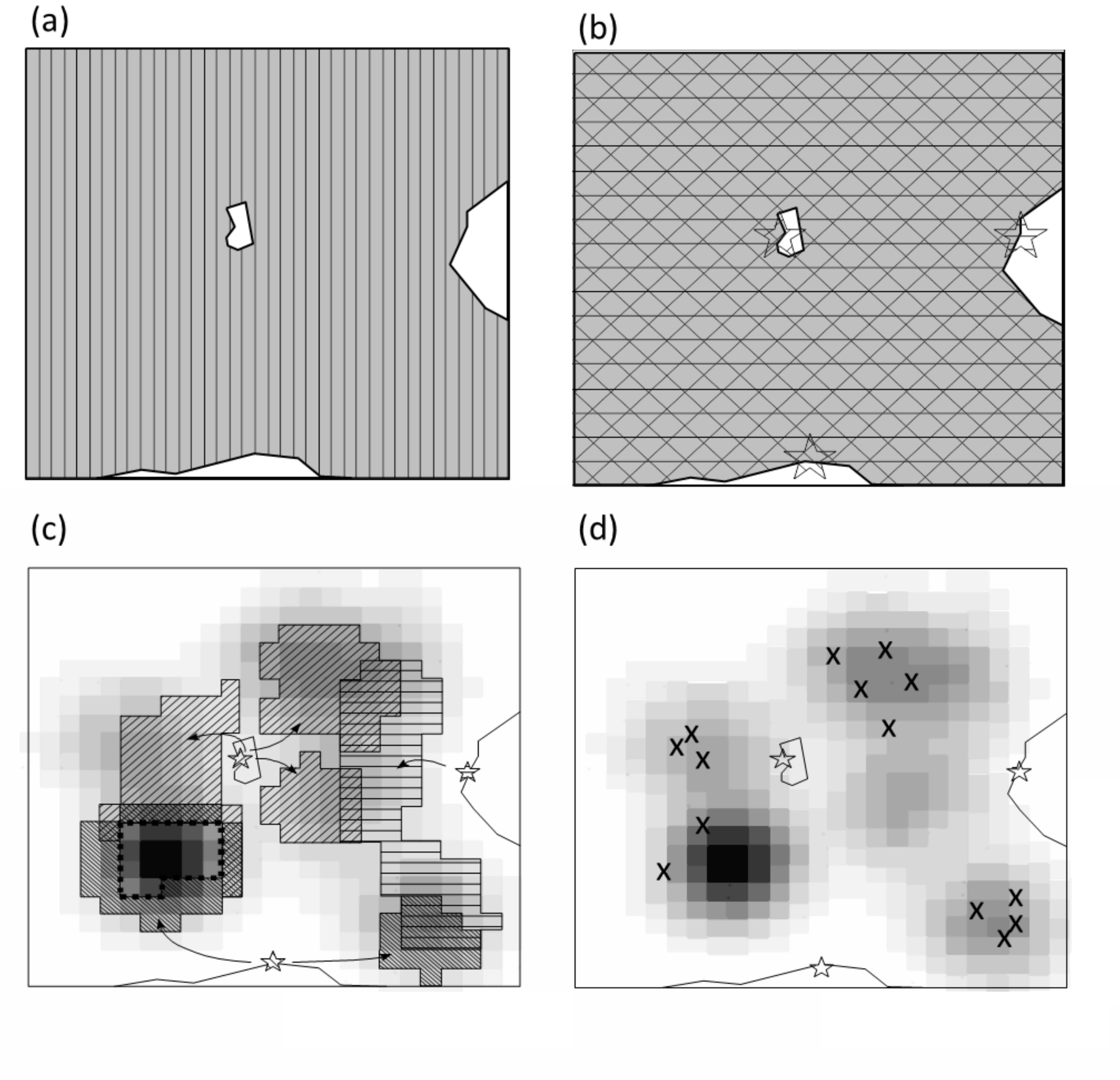



*Figure 2.1 Conceptual view on scales for modeling the fishing mortality F on an hypothetical stock in a given management area (a) Stock-based F applying an overall stock-specific F on the stock; (b) Fleet- or metier-based F after pooling vessels and/or activities with similar exploitation patterns; (c) Spatially and seasonally explicit fleet-based F and (d) Individual vessel-based F describing the catch removal over the area vessel by vessel. Situations a and b are irrespective of the stock distribution while situations c and d are applied on an hypothetical underlying stock abundance distribution (grey levels). From (Ulrich et al., 2012, #7)*

## 2.4 Sensitivity of metiers ' perception to methodological choices

The study by Deporte et al. (2012, #40) illustrates well the differences in metiers definition that can arise when using different criteria, methods and scale on the same dataset. A generic open-source workflow was developed to test and compare a selection of methods, including principal components analysis (PCA), hierarchical agglomerative clustering (HAC), K-means, and Clustering LARge Applications (CLARA) on a large regional dataset consisting of 2008 bottom-trawl logbooks data of five North Sea countries. Depending on the methodological choices made and the level of aggregation, the statistical analyses suggested the grouping of fishing operations into either 6, 8, 11 or 14 groups, with different main target species identified (Figure 2.2).

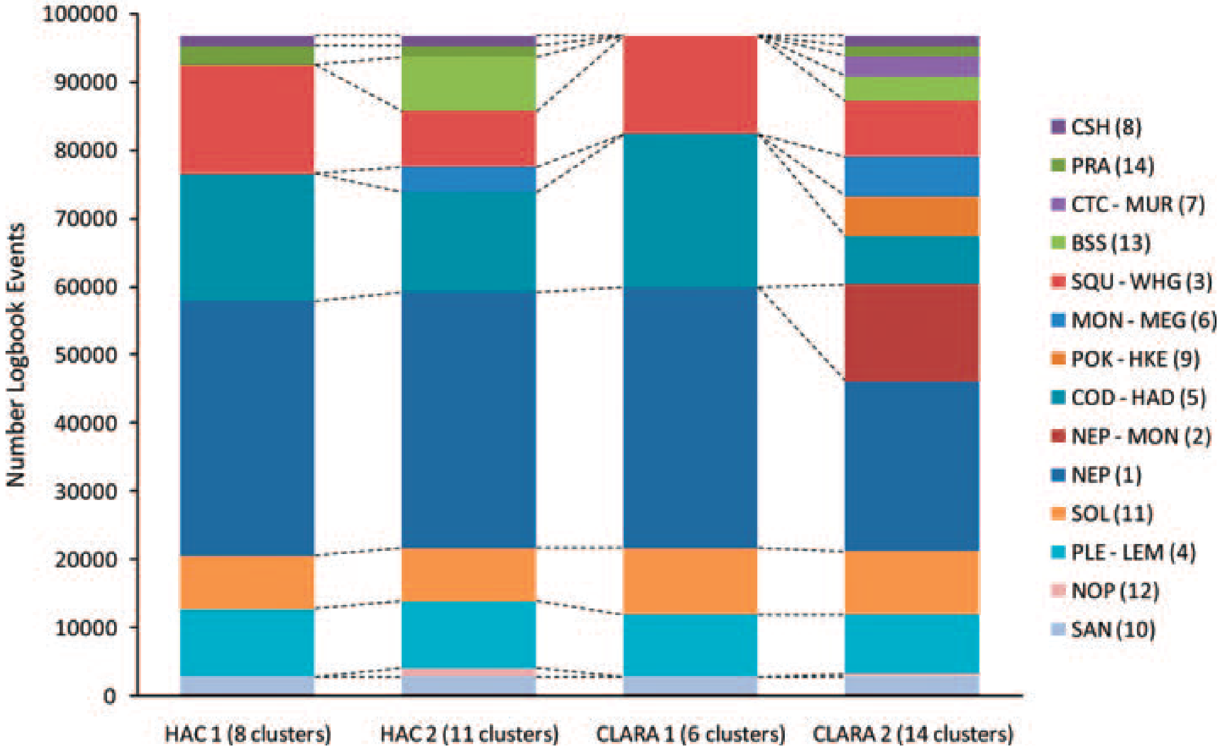



*Figure 2.2. The number of logbook events (fishing operations) obtained with HAC and CLARA at both first and second aggregation thresholds. The horizontal lines indicate how the clusters overlap with each other across the four classifications. From Deporte et al. (2012) Figure 4. Species code in legend follows FAO coding, see Table 1 in Deporte et al. (2012) for the full species name.*

## 2.5 Conclusions on methodological issues in defining fleets and metiers

In conclusion, there is no unique simple set of criteria and methods that can be universally used to define directed fishing. This is mainly due to the variability inherent to the fishing activity and the underlying resource. Catch composition (in species and size) is the result of the species distribution, of the catchability of the gear used and of fine scale tactical features. This means that two vessels with the same characteristics might have different catch profiles and ultimately two consecutive hauls from the same vessel can yield very different outcomes.

As such, using gear, mesh size and fishing grounds to define metiers and directed fishing might be a simpler and more stable criteria to describe a fishing activity; however this is not fully appropriate as these information do not reflect the fine scale tactical decisions made by the individual skippers that drive catch composition and targeting behaviour. On top of that, defining directed fishing based on species distribution (fishing ground) is not stable over time, and will vary with species future distribution and abundance.

For the future, one can note that the ongoing EASME-funded project PROBYFISH (2018-2021), on which I worked at DTU Aqua until my departure in August 2019, builds further on this scientific experience. It intends exactly to propose, among others, an objective, automatic and statistically robust method to define whether a given species would either be a target, a valuable bycatch or a collateral (non-valuable) bycatch of a given fishery, and to develop an interactive and web-based decision-making support tool to help identify suitable threshold values. The method is based on the observed variability in a number of pre-defined catch metrics calculated from standard logbooks and at sea sampling data including discards, and is intended to be easily applicable across all species and regions (ICES, 2020a). The outcomes of such an approach are promising and once completed and published, will potentially provide a useful standard reference method for assessing the robustness of proposed definitions for directed, or targeted fisheries.

## 2.6 Putting this in practice: The definition of demersal mixed-fisheries in the North Sea

North Sea fisheries are very diverse, and often very mixed (i.e. métiers catch several different species). The technical interactions among fishing units are described and monitored annually by the ICES Working Group on Mixed Fisheries, WGMIXFISH (ICES, 2020b). Over the years, some of the approaches described above have been combined with empirical expert knowledge to define fisheries and perform an annual analysis of catch and effort data. Distinction is made between the fleet segment, which describes a group of vessels, and the métier, which describes a type of activity (e.g. a given gear and mesh size targeting a given group of species).

As the lowest level of vessels aggregation, ICES (2020b) uses a segmentation by country (nine categories), gear type (four categories), vessel length class (four categories). This leads to a total number of 42 national fleet segments. These fleets engage in one to five different métiers (different mesh size) and/or areas (including North Sea, Skagerrak or Eastern Channel) each, resulting in 105 combinations of fleet*métier*area, targeting cod, haddock, whiting, saithe, plaice, sole and Nephrops, and catching also a great diversity of other bycatch (ICES, 2020b). These numerous combinations can naturally be aggregated into fewer categories for easing the display and the interpretation of results. The Figure 2.3 illustrates this diversity, emphasizing the number of target species caught by each fleet.

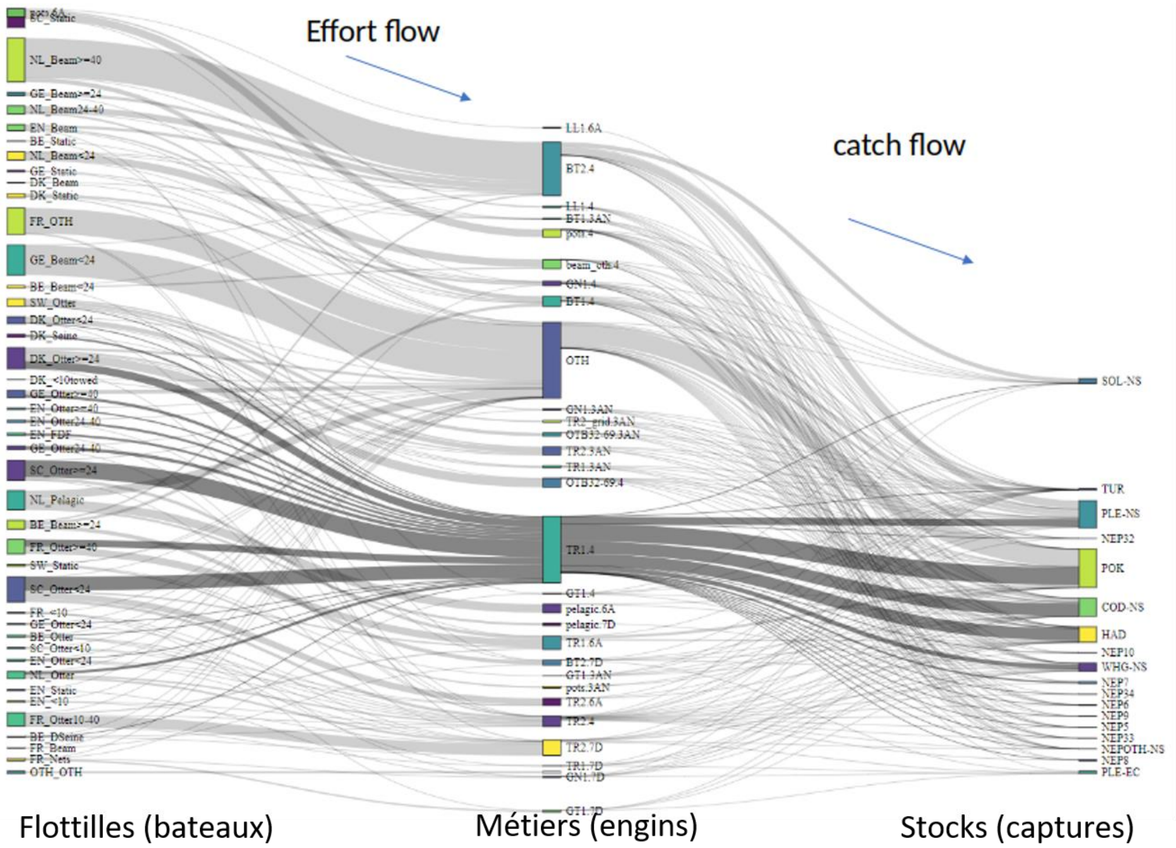



*Figure 2.3. Technical interactions in the North Sea mixed demersal fisheries: 42 fleets segments (country*main gear*vessel size) engaging in 29 metiers (gear*mesh size*fishing area*target species group) and catching mixture of 18 different stocks of 8 species. WHG: Whiting; TUR: Turbot; SOL: Sole; POK: Saithe; PLE: Plaice; NEP: Nephrops; HAD: Haddock; COD:Cod. Built from ICES (2020) data.*

# 3 MSY-based management of mixed fisheries: Examples from the North Sea

*This chapter is partly extracted, and modified as appropriate, from Chapter 2 in (Ulrich, 2016, #3).*

As described above, mixed fisheries like those in the North Sea fisheries are characterised by numerous biological and technical interactions, which create difficulties in identifying MSY targets and achieving those for all stocks simultaneously. As such, important scientific developments have taken place in the last two decades to propose an operational and flexible management approach, which can help achieve the multiple objectives, although trade-offs still requires to be made (Rindorf, Mumford, et al., 2017).

In EU, these scientific developments were undertaken within the EU research projects FP6 EFIMAS (2004-2008) and FP7 project MYFISH (2012-2016)[10], both coordinated by my former institute and team at DTU Aqua; They were also channelled into an operational framework for management advice by ICES, supported since 2006 by the ICES WGMIXFISH working group. Having been a PI and leading scientist in all three fora, this topic of mixed fisheries MSY represents my most important research question over the years, and is worth a chapter in this HDR thesis.

## 3.1 MSY: An appealing old concept but with well-known issues

The problems with the definition and performance of MSY targets in fisheries are well documented, even for a single species, when there are natural fluctuations in the resource (Mace, 2001). If there are multiple interacting species and/or multiple objectives, it becomes even more difficult to evaluate the many trade-offs that inevitably occur and to establish any overall optimised outcome. These issues are not new, and (Larkin, 1977), in its famous epitaph, already stated that single species MSY cannot be achieved simultaneously for all species within an ecosystem when biological interactions (such as predator-prey relationships) are considered. It is also well understood that because of mixed-fisheries interactions, not all stocks can reach MSY at the same pace. The fleets would either not be allowed to fully exploit the more productive ones, or would exploit (and possibly discard) the limiting stock above its FMSY level in order to maximise the economic returns from the other stocks. This dilemma is indeed the cornerstone of mixed fisheries management. While in Europe this leads to situation of overexploitation and "choke stocks", in the US the situation is completely reversed, and managing fisheries according to the least productive stock(s) leads to the under exploitation of key commercial stocks (McQuaw & Hilborn, 2020).

The modelling capacities have improved greatly since the seventies, and numerous advanced scientific studies have been performed in the last fifteen years. Nevertheless, more complex and holistic approaches did not solve these basic questions, and the accumulated evidence demonstrates clearly the inherent difficulties for managers and scientists to (i) agree on a single and simple definition of MSY in an extended and dynamic ecosystem context, (ii) translate this into robust and constant single-stock point estimate FMSY and (iii) manage variable and complex fisheries towards these objectives.

These difficulties will not disappear, as they relate to the intrinsic characteristics of the marine ecosystems and fisheries. They will neither be solved by additional scientific

[10] https://www.myfishproject.eu

modelling. The natural fluctuations of productivity and the multiplicity of ecological, economic, social and institutional objectives call for the acceptance of the needs to making trade-offs. One pragmatic approach forward has thus been to give more importance to avoiding risks of adverse outcomes than to optimising exactly the exploitation patterns across a given set of criteria to be defined (Paul Degnbol, 2015). In this sense, the MSY objective is still appealing in spite of the concerns summarised above (Mace, 2001; Patrick & Link, 2015): it induces higher yields, better ecosystem status and higher profitability than the previous European "precautionary" framework for fisheries management. Being formulated more explicitly in the 2013 CFP than in any previous CFP, MSY should ensure that the fishing mortality for European stocks is maintained in the future at levels significantly below those observed in the past.

Thus, a key development of science in the last decade has been to work towards an adaptation and modernisation of the MSY concept rather than wholesale replacement.

## 3.2 Exploring this in practice: challenges with reaching MSY for all stocks simultaneously in the North Sea ecosystem

The North Sea has traditionally been the most studied and modelled area in European fisheries. Earliest records on the idea of a Maximum Sustainable Yield are found in the late XIX century, when hypotheses started developing to explain the observed variability of North Sea fish stocks (Degnbol, 2015). This question triggered the creation of the first global organisation for marine science, The International Council for the Exploration of the Sea (ICES) in 1902. Later, it is also in the North Sea that the founding theories of fish stock dynamics emerged, including the hypotheses on the variability of year-class strengths (Hjort, 1914), the equilibrium yield curve with a MSY top (Graham et al, 1935), and the first age-structured population model accounting for the annual variability of growth and productivity (Beverton & Holt, 1957). Since the time of these early pioneers in fisheries science, continued development in fisheries modelling has taken place on the North Sea fish stocks, which are now among the most studied in the world. The quantity and quality of fisheries data and models available is high, both at the single-stock level and at the ecosystem and regional scale.

Two main types of interactions influence the estimation of MSY and the ability to reach it: The biological interactions (foodwebs), and the technical interactions (mixed fisheries). In the North Sea, both have been extensively studied, and described in various ICES documents.

### 3.2.1 Biological interactions

The North Sea is characterized by many and strong biological interactions (Figure 3.1, ICES, 2013), which are quantified using a predator-prey assessment model parameterized on historical stomachs samples for the main commercial species (Lewy & Vinther, 2004). Top predators form an important part of the food web, including numerous charismatic species such as seabirds and marine mammals that eat fish. Within the fish community a number of fish eat other fish, and some of those spend only part of their time in the North Sea.

The fish species can be divided into four categories: forage (prey) fish, which are also targeted directly by the fishery (herring, sandeel, sprat, Norway pout); fish that eat small fish (e.g. whiting, haddock, grey gurnard, starry ray); benthic-feeding fish (flatfish like sole, plaice and turbot), and fish that eat large fish (top predators like cod and saithe).

A very important feature is that due to a successful reduction in fishing mortality for many stocks, natural mortality is becoming a dominant source of mortality in the North Sea. This means that the stock dynamics are increasingly influenced by natural processes and not by fisheries only. Understanding the role of other non-fish top predators, such as seals and cetaceans, is also important, particularly since these predator populations are expected to increase further in the future.

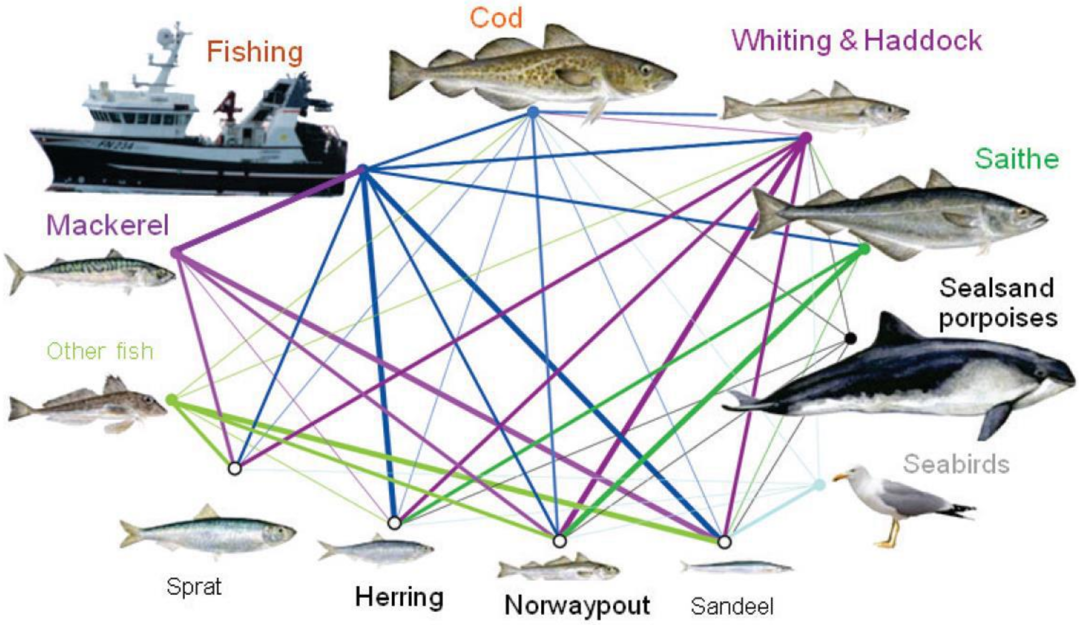



*Figure 3.1. Overview of the important predators and prey in the North Sea SMS model foodweb. Other fish include grey gurnard, North Sea and western horse mackerel, and starry ray. Seabirds include fulmar, gannet, great black-backed gull, guillemot, herring gull, kittiwake, puffin, and razorbill. Seals and porpoises include grey seal and harbour porpoise. An "Other food" pool with constant biomass is included in the model to represent all prey types that are found in the stomachs but that are not modelled explicitly (e.g., crustaceans, mollusks, other prey fish).The colour of the line indicates which predator the species is eaten by, the thickness of the line Indicates the biomass removed in this interaction (average from 1963 to 2010). Source: (ICES, 2013), Figure 6.3.1.1*

### 3.2.2 Technical interactions

The technical interactions in the North Sea have been described in Section 2.6 above.

In the CFP prior to the 2013 landing obligation, increased awareness on the high levels of discarding in EU fleets led to the recognition that single-species management is in itself a cause of discarding in mixed fisheries, because management objectives for the individual stocks may not be consistent with each other although the species are caught simultaneously in unselective fishing operations. The total allowable catch (TAC) of one species may be exhausted before the TAC of another, leading to catches of valuable fish that cannot be landed legally. Conceptually, this implies that the fleets may be constrained by the stock with the smallest relative quota, the "choke stock". The choke stock can be the least productive stock (which can be either a target e.g cod, sole or whiting or a bycatch e.g. turbot) or the stock with quota imbalance compared to historical right allocations (e.g. hake).

### 3.2.3 Other ecosystem considerations

Beyond the predator-prey and the technical interactions described above, other aspects that may affect the achievement of $F_{MSY}$ will be the constraints imposed by the Marine Strategy Framework Directive (MSFD), with the need to achieve Good Environmental Status (GES) in EU Waters.

There are important activities going on regarding this topic, closely involving ICES and EU Member States. Of particular importance for fisheries management is the consideration of bycatch species. The impact of demersal fisheries on the seafloor and on fish habitats is another important issue. As these discussions are still very much in progress by the time of writing this report, they are not further detailed here, but this should be kept in mind in the policy considerations. ICES now publishes integrated ecosystem overviews for several ecoregions[11], including the North Sea, which provide a useful source of knowledge for ecosystem-based marine management.

## 3.3 Fcube model and the ICES mixed-fisheries advice

In collaboration with others, I thus worked to develop a modelling framework to formalise and analyse the dilemma explained above of either not being allowed to fully exploit the more productive stocks, or to overexploit (and possibly discard) the least productive ones. In this aim, the FCube model (Fleets and Fisheries Forecast, (Ulrich et al., 2011 #8, as well as publications #43, 44, 49, 50) was first proposed to ICES in 2006. It built on the simulation ideas I had developed earlier, during my PhD with the BECHAMEL model (Ulrich, Le Gallic, et al., 2002, #13) and post-doc/early carrier with the EEQ (Ulrich, Pascoe, et al., 2002, #14) and TEMAS (Ulrich et al., 2007, # 11) models.

Before that, this important issue was not quantified and not accounted for in traditional management advice. Based on usual catch and effort information, the FCube model was thus developed to estimate the catch potentials of distinct fleets (groups of vessels) and métiers (type of activity), and hence to quantify the risks of over- and underquota utilization for the various stocks.

In 2009, after three years of further developments and refinements, the approach was considered suitable enough by ICES to be included in the annual advice for the North Sea. To support this, the ICES WGMIXFISH Working Group was launched[12], which has met twice a year since that time, and now regularly produces such an advice not only for the North Sea, but also for the Celtic Sea, the Bay of Biscay, the Iberian coast; similar approaches are in progress for the Irish Sea and West of Scotland. In 2019, this mixed-fisheries advice was further developed with new elements added, to form the now called « Fisheries overviews »[13].

Considering that (i) being published and presented to stakeholders, this text is the best descriptor of the approach followed and of the interpretation and understanding of its results; (ii) this summarises my central involvement and leadership in this work in almost fifteen years; and (iii) I thus personally extensively contributed to writing this text in previous years, I choose to quote a part of the 2019 ICES fisheries overview for the Greater North Sea (ICES, 2019) in this HDR. This reads as follows:

*Mixed-fisheries considerations are based on the single-stock assessments, combined with information on the catch composition and fishing effort of the demersal fleets and fisheries in the Greater North Sea which catch cod (cod.27.47d20), haddock (had.27.46a20), whiting (whg.27.47d), saithe (pok.27.3a46), plaice (ple.27.420 and ple.27.7d), sole (sol.27.4), turbot (tur 27.4), and Norway lobster Nephrops norvegicus (functional units [FUs] 5–10, 32, 33, 34, and 4 outFU). In the absence of specific mixed-fisheries management objectives, ICES does not advise on specific mixed-fisheries catch opportunities for the individual stocks. The mixed-fisheries results shown for Norway*

[11] https://www.ices.dk/advice/advisory-process/Pages/Ecosystem-overviews.aspx
[12] https://www.ices.dk/community/groups/Pages/WGMIXFISH.aspx
[13] http://ices.dk/advice/advisory-process/Pages/fisheries-overviews.aspx

*lobster are combined for several functional units (FUs) in plots, but stock status and fishing opportunities differ across FUs.*

*Mixed-fisheries scenarios are based on central assumptions that fleet fishing patterns and catchability in 2019 and 2020 are the same as those in 2018 (similar to procedures in single-stock forecasts, where growth and selectivity are assumed constant). Beginning with this year's advice, the assumptions for the MIXFISH scenarios for the North Sea have been modified to more realistically reflect choke situations, i.e. where one or more national quotas are fully utilised, all fishing will cease for that Member State (MS). If a MS has unused quota for a given stock, that stock shall not be estimated to be a choke species for the fleets of that MS, making the hypothesis that national quotas are easier to reallocate between fleets than countries. To forecast catches, recent catchability and fishing mortality are calculated by national fleet.*

*Mixed-fisheries projections are presented in terms of catch (wanted + unwanted catch). The most limiting TAC in 2020 will be the TAC for cod for particular fleets ("cod-ns" scenario). The "Min" scenario gives a 14% higher catch of cod compared to the "cod-ns" scenario, due to the relaxing of the constraint on a stock where the country is not assumed to be limited for that stock, but the model does not take into account quota reallocation between fleets. Substantial overshoot of TACs can occur under other scenarios (e.g. "Max" scenario). The mixed-fisheries results shown for Norway lobster are combined for several FUs in plots, but stock status and fishing opportunities differ across FUs.*

*The potential for quota over- and undershoot linked to the most and the least restrictive single-stock fishing opportunities for 2020 is presented in Figure 3.2. Six projections are presented, corresponding to different fleet scenarios for 2019 and 2020.*

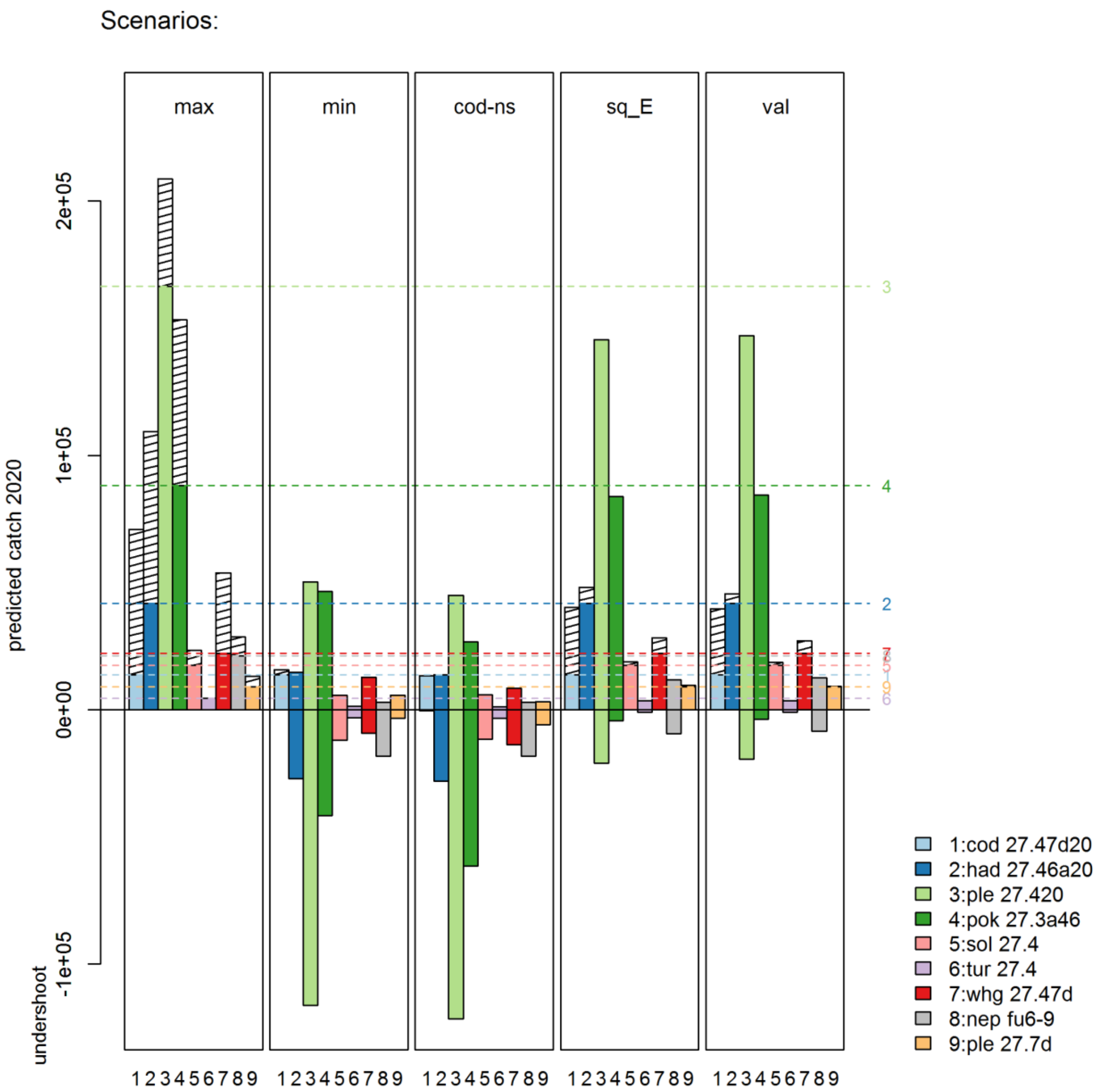



*Figure 3.2. Mixed fisheries for the North Sea. Mixed-fisheries projections. Estimates of potential catches (in tonnes) by stock and by scenario. Horizontal lines correspond to the single-stock catch advice for 2020. Bars below the value of zero show undershoot (compared to single-stock advice) where catches are predicted to be lower when applying the scenario. Hatched columns represent catches that overshoot the single-stock advice.*

*Scenarios*

*Max : "Maximum": For each fleet, fishing effort in 2020 stops when all stock shares* of that fleet have been caught up. This option causes overfishing of the single-stock advice possibilities of most stocks.*

*Min : "Minimum": Choke species are assessed at the country level comparing the sum of fleet catches and catches at status quo effort for each fleet, assuming that quota reallocation between fleets can occur at country level. For each fleet, fishing effort in 2020 stops when the most limiting of the predefined choke stock shares of that fleet is attained. If a fleet has no identified choke stock then the status quo effort for that fleet is used. This option causes underutilization of the single-stock advice possibilities of other stocks. This scenario can highlight some potential "choke species" issues*

*Sq_E "Status quo effort": The effort of each fleet in 2019 and 2020 is set equal to the effort in the most recently recorded year for which landings and discard data are available (2018).*

*Val: "Value": A simple scenario accounting for the economic importance of each stock for each fleet. The effort by fleet is equal to the average of the efforts required to catch the fleet's stock shares of each of the stocks, weighted by the historical catch value of that stock (see example further below). This option causes overfishing of some stocks and underutilization of others.*

*COD-ns: "Cod MSY approach": All fleets set their effort in 2019 and 2020 corresponding to their cod stock share, regardless of other catches. (There are small differences in the cod catches between this scenario and the single-stock advice because of the slightly different forecast methods used.) This option is the most precautionary option, causing underutilization of the single-stock advice possibilities of other stocks. This scenario can highlight some potential "choke species" issues.*

*Catch scenarios*

*Mixed-fisheries advice considers the implications of mixed fisheries operating under single-stock TAC regimes, taking into account the fishing patterns of the various fleets in 2018. The scenarios presented here do not assume any quota balancing through changes in targeting behaviour (i.e. changes in catchability and/or in effort distribution) and/or changes in access to quota, although the model used would allow investigating such alternative scenarios in the future.*

*The ICES single-stock catch advice for demersal stocks in 2020 is based on either the existing management plans, the ICES maximum sustainable yield (MSY) approach, or the ICES precautionary approach. Mixed-fisheries catch scenarios can take specific management priorities into account. (…).*

*Scenario results show that it is not possible to achieve all management objectives simultaneously under the current fishing patterns. For instance, if decreasing the fishing mortality for cod is the major objective and fleets stopped fishing after exhaustion of their cod TAC, this could mean that the TAC for other species in the mixed fisheries may not be fully utilized. As a consequence, scenarios that result in under- or overutilization are useful in identifying the main mismatches between the fishing opportunities of the various stocks, where limiting TACs can create potential "choke species" effects at fleet level. Such scenarios indicate the direction fleets may have to adapt to fully utilize these catch opportunities without increasing the risk of unwanted catch.*

*North Sea cod is estimated to be the most limiting stock in the Greater North Sea mixed-fisheries model. The assessment of cod has indicated that its SSB for 2019 is below Blim, with advised catch rates for 2020 below Fmsy in order to achieve an SSB > Blim in 2021. For 2020, assuming a strictly implemented landing obligation (corresponding to the "Min" scenario), cod is estimated to constrain 22 out of 42 fleet segments (…). Plaice stocks are the next most limiting stocks, constraining ten fleet segments (6 for North Sea plaice and 4 for Eastern Channel plaice). 9 fleet segments are assumed not to be limited by any stock (the quota is assumed not to be limiting for the species they are targeting). Conversely, in the "Max" scenario, North Sea plaice, saithe and turbot would be the least limiting for 20, 5 and 5 fleet segments, respectively. Finally, if Norway lobster were managed by separate TACs, Norway lobster in FU 7 would be the least limiting for seven fleet segments.*

*ICES single-stock advice provides TACs according to the ICES MSY approach or the MAP. To be consistent with these objectives a scenario is necessary that delivers at least the SSB and/or F objectives of the single-stock advice simultaneously for all stocks considered. This is achieved in the "Min" scenario, which assumes that fleets stop fishing when their first stock share is exhausted, regardless of the actual importance of this stock share for the fleet. This scenario reflects the "choke species" effect that may result from a strictly implemented landing obligation without adaptation of the fleets. Total fishing effort in 2020 should be reduced by 50% of its 2018 level to comply with this scenario, consistently with the reductions in fishing mortality advised for cod. For some fleets effort may need to be reduced much more than 50%.*

*In contrast to the "Min" scenario, the "Max" scenario demonstrates the upper bound of potential fleet effort and stock catches. Clearly, the assumption that all fleets continue fishing until all their stock shares are exhausted irrespective of the economic viability of such actions does not make it a highly plausible scenario. Its purpose is mainly to illustrate where the imbalance lies. The different fleets have different opportunities and incentives for 2019 and 2020, depending on their historical catch composition and catchability, and on the differences in productivity across the various stocks that they exploit. In 2020 the fleets catching any amount of Norway lobster, saithe, and plaice would have to increase their effort on average by 65% to achieve their stock shares for these stocks, which would lead to potentially large overshoots of their shares for other stocks. This is an unrealistic outcome for such fleets, especially considering that the TAC for saithe and plaice is not fully taken at present (total catches were around 70% of the catch advice in 2018 for these two stocks).*

*Two intermediate scenarios reflect alternative mixed-fisheries hypotheses: "SQ_E" and "Value".*

*The status quo "SQ_E" scenario sets the effort of each fleet in 2019 and in 2020 equal to the effort in the most recently recorded year for which data are available (2018). This scenario investigates the mixed-fisheries outcomes if the situation remains the same in terms of total effort and effort allocation among métiers. This situation presents a potential 2020 TAC overshoot for cod, haddock, whiting, North Sea sole, Eastern Channel plaice, and a 2020 TAC undershoot for saithe, North Sea plaice, turbot, and a number of Norway lobster stocks.*

*In the absence of a full economic behaviour model, a "Value" scenario was run that balances fishing opportunities by stock with their potential market value. This scenario usually predicts effort levels closer to the realised effort than the "Min" and "Max" scenarios (Ulrich et al., 2011). For 2020, the "Value" scenario estimates results close to the status quo "Sq_E" scenario.*

*This year, a "COD-ns" scenario is presented. This scenario reflects the fishing mortality corresponding to the single-stock advice for cod (based on the ICES MSY approach), and the results present fishing opportunities for other stocks in a mixed-fisheries context.*

*(…)*

## 3.4 Adapting single-stock MSY concept to a changing environment: MSY ranges and regional multiannual management plans

### 3.4.1 Scientific analyses

Regarding single stocks, important progresses have been achieved in understanding the causes of the variability of growth and productivity over time, especially when trends are observed beyond the annual fluctuations. In particular, the role of the increasing temperature has often been advocated, as this can affect many biological and physiological processes. Nevertheless, the truth remains that in most cases, the variability of the system cannot be fully explained and, more importantly, cannot be accurately predicted for the future. Instead, the scientific efforts have rather focused on the best way to integrate this variability as a key input to MSY estimation.

In particular, much focus has been given to the handling of the uncertainty linked to the relationship (SRR) between spawning stock biomass (SSB, the parental biomass) and the recruitment (number of offsprings). $F_{MSY}$ is primarily sensitive to whereas it is assumed that the SRR is rather flat (above a given level of biomass, recruitment fluctuates around average without trends, "Hockey-Stick" shape), rather increasing (higher biomass gives higher average recruitment, asymptotic "Beverton and Holt" shape, leading to a lower $F_{MSY}$) or rather dome-shaped (above a given level of biomass, the average recruitment might decrease due to density-dependent effects, i.e. negative effects that occurs when the density (numbers per unit of area) of animals increase: typically increased predation including cannibalism and/or food or habitat shortage; "Ricker" shape, leading to a higher $F_{MSY}$) (Figure 3.3). In most cases though, the time series of observed recruitment does not clearly follow any of those three choices, but is a more scattered cloud of points.

To account for this uncertainty, a probabilistic and stochastic framework was developed including all three options. In addition, attention was paid to include precautionarity in this framework, so that the risk of falling below Blim should be low (<5%, with the corresponding fishing mortality noted FP.05) when fishing at $F_{MSY}$ over a long period of time (Figure 3.4, red line in the right panel) This work culminated in an ICES Workshop in late 2014, which applied this framework to most stocks in the Baltic Sea and North Sea and provided consistent $F_{MSY}$ and precautionary FP.05 estimates (ICES, 2015b, 2015a).

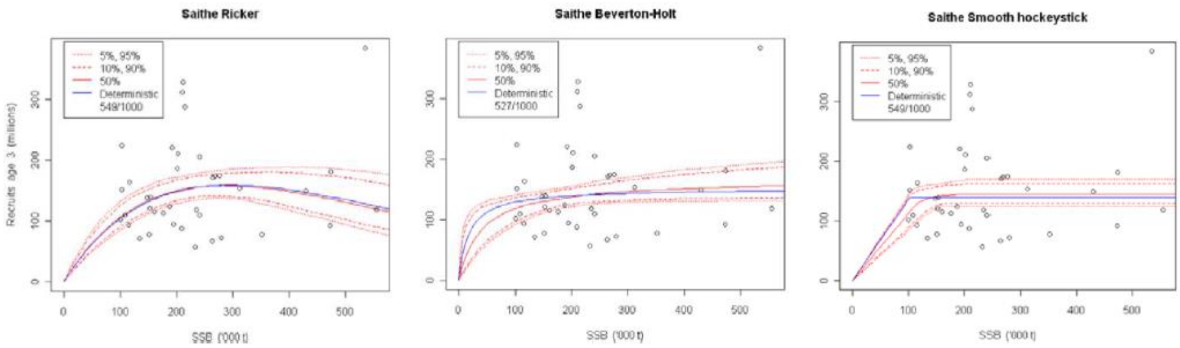



*Figure 3.3 Different stock-recruitment relationships fitted to North Sea saithe. Source : (ICES, 2010a), figure 11.9.1*

The outcomes of this work showed clearly and consistently that given the annual fluctuations in growth, productivity and selectivity, it is difficult to provide a single value of

$F_{MSY}$. The estimated long-term Maximum Yield can be obtained with a range of fishing mortalities, depending of the combination of these biological and fisheries parameters. Taking Eastern Channel sole as an example below (Figure 3.4), we can see that different long-term yields can be obtained for any given level of fishing mortality (interval in between dotted lines on left panel).

Turning this around, this implies that the average highest yields can also be obtained with several F values, here between 0.2 and 0.4 (red line left panel, plotted correspondingly as a probability distribution in the brown line, right panel).

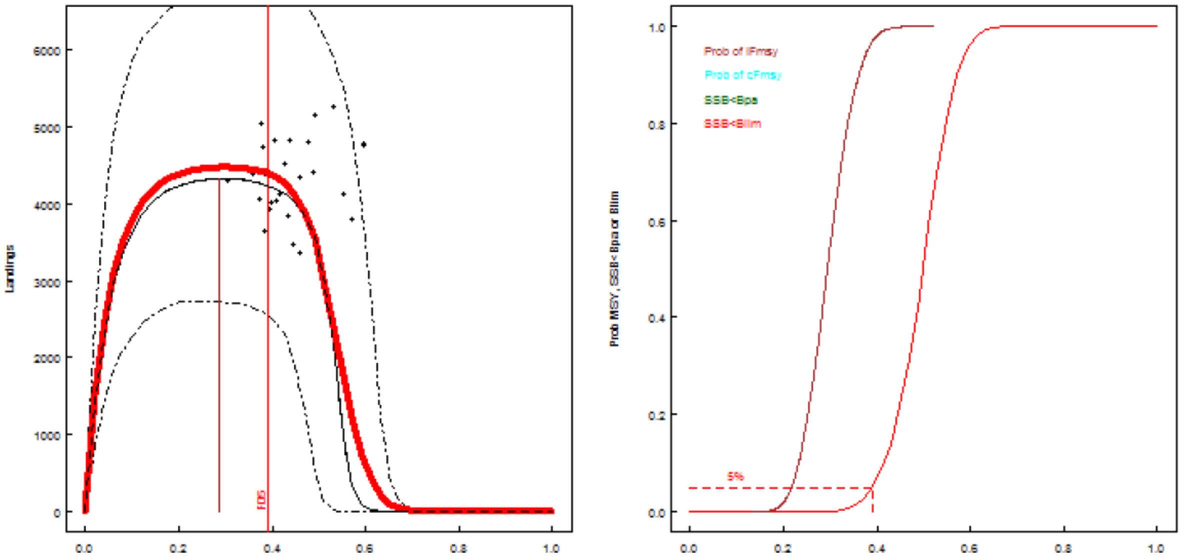



*Figure 3.4. Summary plot for Sole VIId. Left: historic values (dots), mean (solid red), median (solid black) and 90% intervals (dotted black) landings for exploitation at fixed values of F. Right: probability of SSB<Blim (red, with FP.05 shown with the dotted line) and the cumulative distribution of FMSY (brown). Source : (ICES, 2015g), Figure 6.16.4*

This means that the $F_{MSY}$ point-estimate that is finally produced as the key result of this work (ICES, 2015a) is an average (median) across many plausible future developments in the stock, based on historical observations of both high and low productivity periods. This value could be kept constant for some years, provided that the current productivity does not vary outside the assumptions made on the basis of these historical observations.

Another important finding of this study was the observation that for most short-lived and small fish, the $F_{MSY}$ is very close to the precautionary FP.05, while a number of large fish (able to grow larger than 60 cm) stocks can potentially sustain high and precautionary yields across a range of fishing mortality (ICES, 2015b). For these stocks, long-term fishing at F values which are slightly higher or lower than the average $F_{MSY}$ can deliver average yield quite close to the estimated maximum. For such F values higher than $F_{MSY}$, this implies average biomass levels slightly lower than at $F_{MSY}$, but with a probability of at least 95% of staying above $B_{lim}$.

### 3.4.2 Political process around regional multiannual management plans

In parallel to this scientific work developed in ICES and in the EU research project MYFISH, the EU Commission also discussed these issues from a policy point of view, in order to implement the objectives defined in the 2013 CFP of achieving MSY for all stocks and implementing management plans at regional level instead of individual stock-by-stock plans. A task force (EU, 2014) comprising the three main EU Institutions (EU Commission, EU Parliament and EU Council of Fisheries Ministers) suggested to use $F_{MSY}$ ranges as flexible targets for the regional management plans rather than prescriptive Harvest Control

Rules (STECF, 2015), de-facto considering MSY as a desirable multi-dimensional area rather than a point estimate. The idea started thus to emerge that the MSY concept could be extended into a multidimensional area, the "Pretty Good Yield" (PGY) area (as named by Hilborn, 2010). This idea means that a part of the maximum yield could be traded off against the achievement of the other objectives, in particular regarding mixed-fisheries conflicts in the frame of regional management plans and the landing obligation.

ICES was thus tasked by the EU Commission to identify a range of precautionary F values that would deliver a PGY, and a threshold of at least 95% of the maximum estimated average long-term yield in a single-stock approach was chosen. The boundaries of this area are the so-called FMSY ranges (ICES, 2015b) (Figure 3.5).

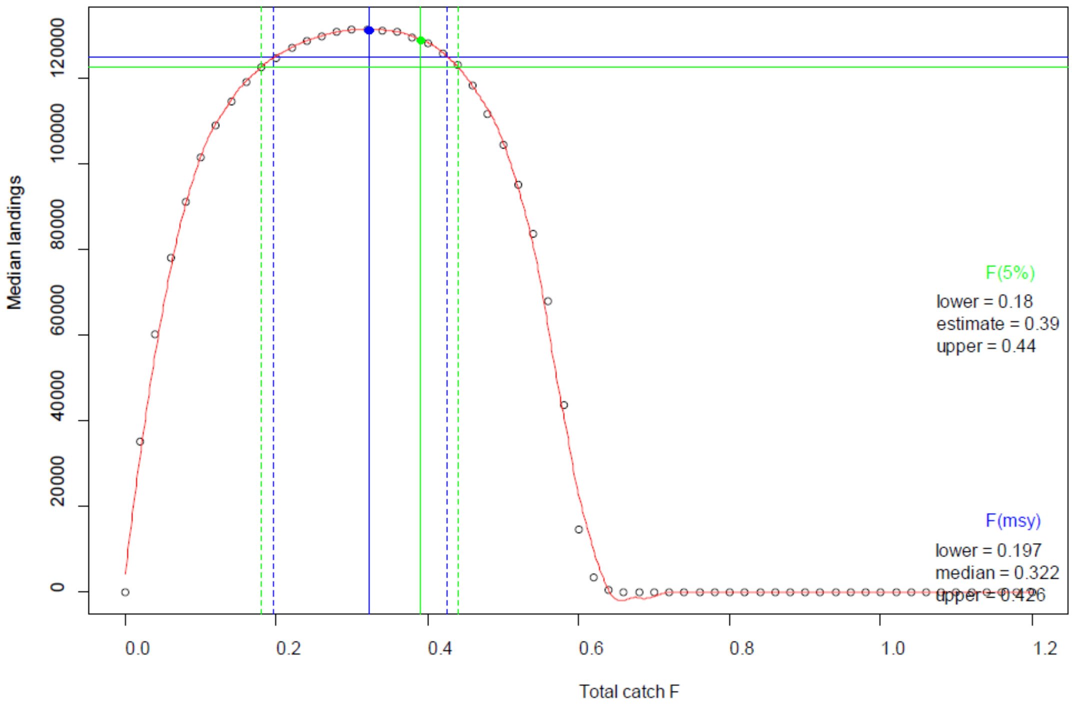



*Figure 3.5. Median landings yield curve with estimated reference points for North Sea saithe, with fixed F exploitation from F= 0 to 1.2. Blue lines: median FMSY estimate (solid) and range at 95% of maximum yield (dotted). Green lines: precautionary FP.05 estimate (solid) and range at 95% of yield at FP.05 (dotted). Source: (ICES, 2015b), Figure 6.12.2*

There have however been many discussions whether $F_{MSY\text{-}upper}$ is truly an acceptable MSY reference point. ICES underlined that using ranges and deciding upon the PGY threshold (here 95%) is a policy decision that can help balance trade-offs, not a scientific one. (ICES, 2015a) noted the following: "*In a single-species context fishing above $F_{MSY}$ implies reduced stock biomass and this may be substantial where $F_{upper}$ is much higher than $F_{MSY}$. So in utilizing $F_{MSY}$ ranges there are more advantages to fishing between $F_{MSY}$ and $F_{lower}$ than between $F_{MSY}$ and $F_{upper}$.*

*With higher fishing mortalities the following occurs:*

*• A need for increased fishing effort;*

*• Higher dependence of stock and yield on recruiting year classes and increased variability on catch opportunities;*

*• The size of the fish in the stock and the catch will be smaller on average;*

*• Greater probability of SSB being less than MSY Btrigger, implying that advised catches would have to be reduced more often according to the sliding rule used in ICES advice;*

*• A lower probability of density-dependent effects such as reduced growth or increased cannibalism.*

*For some mixed fisheries it may be difficult to reconcile the Fs on different stocks. An approach for maximizing long-term yield could be to attempt to reconcile F on a mixed fishery using Fs between $F_{lower}$ and $F_{MSY}$. If this cannot be accomplished, F between $F_{MSY}$ and $F_{upper}$ could also be used in the short term. However, using $F > F_{MSY}$ for the same stock in the long term implies that there are structural changes required in the fishery to avoid the consequences listed above*."

Following this early work in 2015, a long and contentious political process engaged between the three EU institutions, to frame this approach into EU legislation. Many uncertainties remained on the use of MSY ranges to fix annual TACs. Noticeably, my former colleague at DTU Anna Rindorf and I were tasked to give two 2-days courses on MSY and MSY ranges, one in EU Commission in DG Mare in 2016 and one in the European Parliament in 2017, to clarify managers on the scientific basis underpinning this new approach.

Ultimately, a first regional multiannual was agreed for the Baltic Sea in 2016, then in the North Sea in 2018, in the Western Atlantic waters in 2019 and, for the first time in the Mediterranean Sea, for the Western Mediterranean demersal fisheries in 2019[14] . Incidentally, I chaired the suite of five Experts Working Groups of the STECF (EWGs 18-09, 18-13, 19-01, 19-14, 20-13) in charge of evaluating that new form of regional management in the Mediterranean Sea[15].

[14] See legal references for all the plans at https://ec.europa.eu/fisheries/cfp/fishing_rules/multi_annual_plans_en

[15] https://stecf.jrc.ec.europa.eu/reports/management-plans

## 3.5 MSY Ranges and mixed fisheries

The implementation of these regional plans combined with the implementation of the landing obligation raised new questions for providing suitable scientific mixed fisheries advice. In addition to reasoning in terms of "likelihood of overquota catches" as performed since 2009 (Figure 3.2), we developed a new approach to identify a potential "optimal advice" within the space of potential TACs between the ranges of Fmsy-lower and Fmsy-upper of several stocks, a space we commonly refer to as "the potato of opportunities" (Figure 3.6).

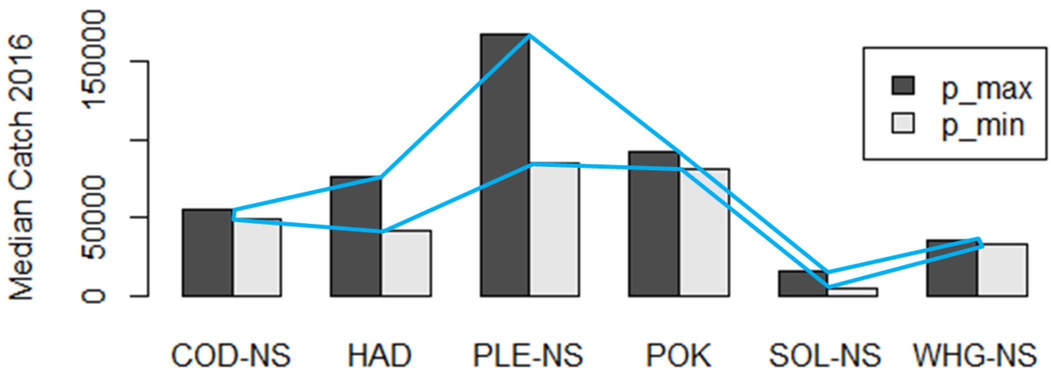



*Figure 3.6. Illustration of the "potato of opportunities": space of potential fishing opportunities (TAC advice for the following year) for each stock of the mixed fisheries plan corresponding to fishing mortality between Fmsy-lower and Fmsy-upper. Presentation to ICES Annual Science Conference 2016.*

This approach, published in (Ulrich et al., 2017, #2), is now included in the ICES fisheries overview and explained as follows (quoting again from ICES, 2019) :

*For those demersal fish stocks for which the FMSY range is available, a "range" scenario is presented that minimizes the potential for TAC mismatches in 2020 within the FMSY range. The "range" scenario* (Ulrich et al., 2017) *searches for the minimum sum of differences between potential catches by stock under the "Min" and the "Max" scenarios within the $F_{MSY}$ ranges. This scenario thus estimates a fishing mortality by stock which, if used for setting single-stock fishing opportunities for 2020, may reduce the gap between the most and the least restrictive TACs, thus reducing the potential for quota over- and undershoot.*

*This "range" scenario suggests that the potential for mixed-fisheries mismatch would be lowered with a 2020 TAC in the lower part of the $F_{MSY}$ range for North Sea and Eastern Chanel plaice and North Sea saithe, and at the highest possible value for cod in accordance with the MSY approach and the EU multiannual plan (MAP; EU, 2018).*

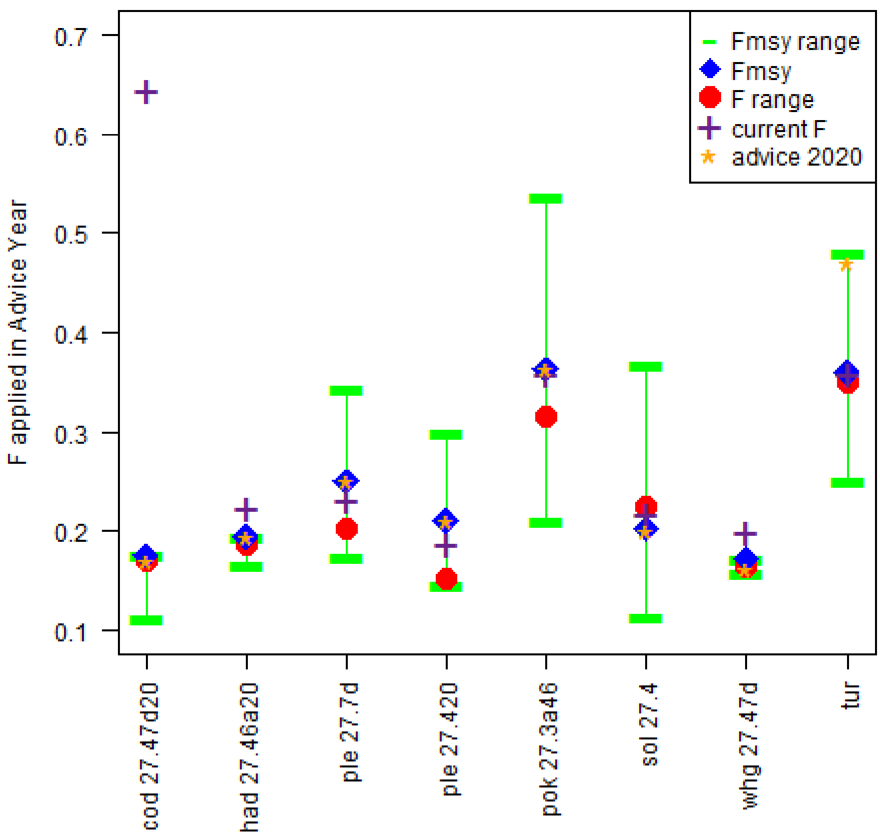
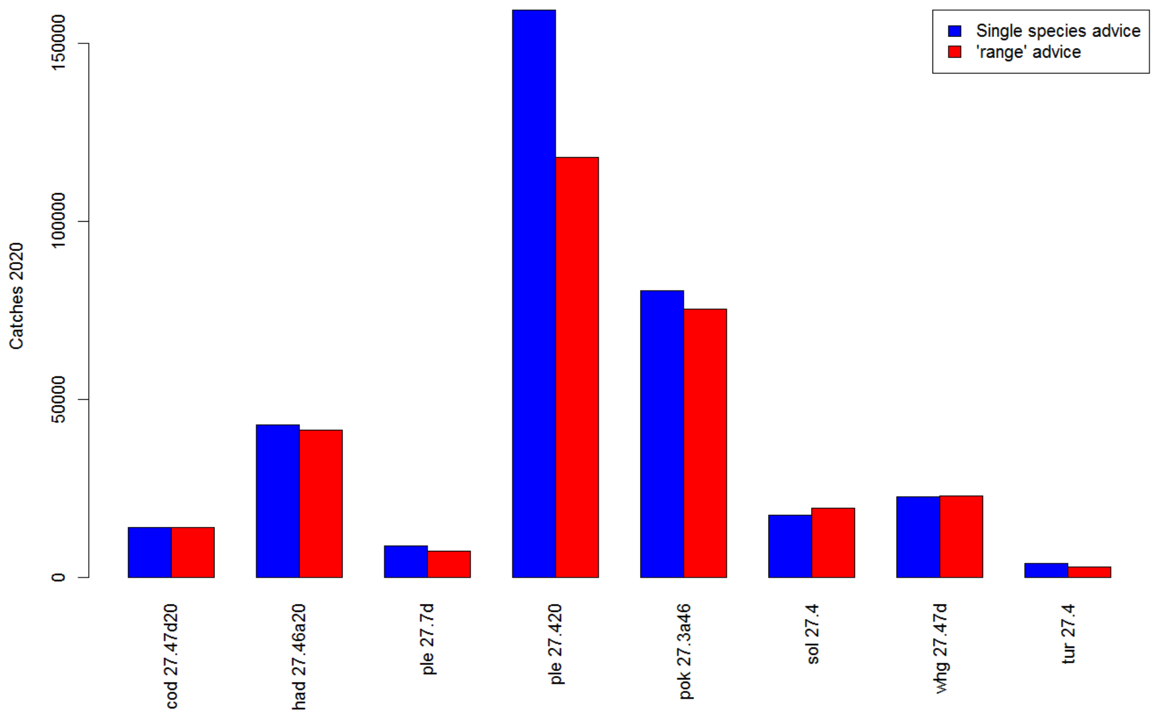



*Figure 3.7. Mixed fisheries for the North Sea. North Sea mixed-fisheries 2020 "range" fishing mortality within the $F_{MSY}$ range, compared with $F_{MSY}$, the current F (F in 2018), and F in the single-stock advice for 2020. The "range" F is the one giving the lowest difference in tonnage between the "Max" and the "Min" scenario across all stocks and fleets. For cod in the North Sea, $F_{MSY}$ ranges are limited in accordance with the MSY approach and the MAP when below MSY $B_{trigger}$ (from ICES, 2019).*



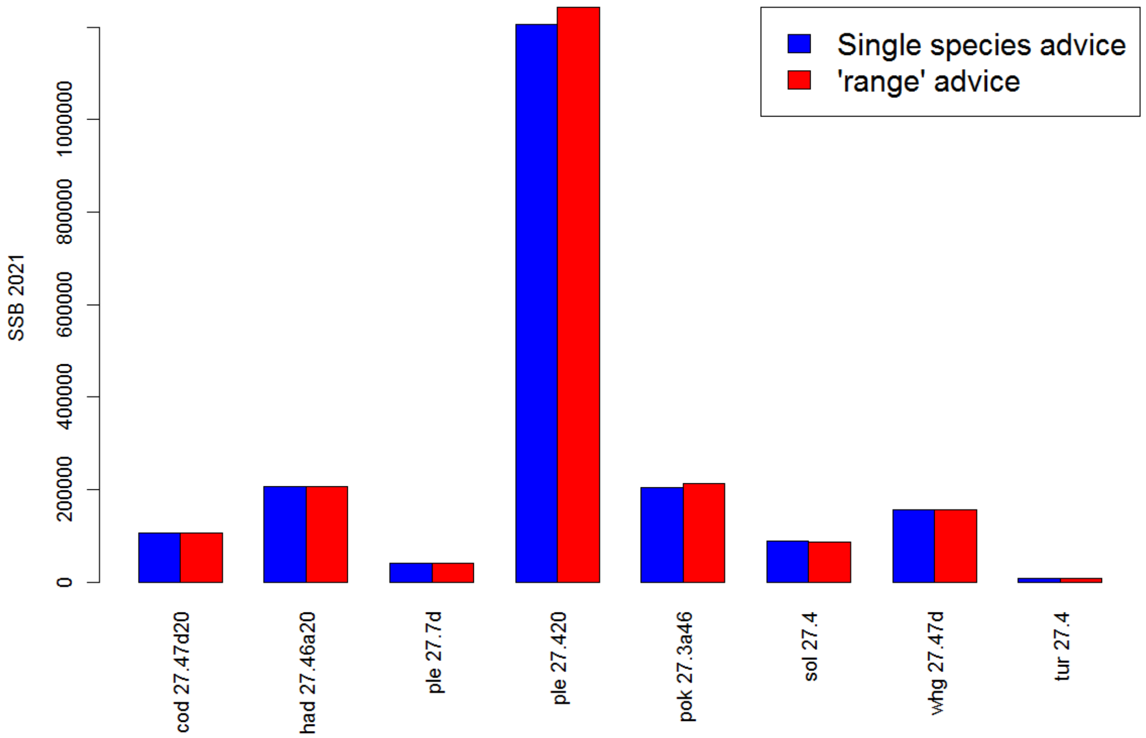




*Figure 3.8. Mixed fisheries for the North Sea. Comparison of the outcomes in terms of total catches in 2020 (left) and SSB in 2021 (right) between the $F_{MSY}$-based single-stock advice and the $F_{range}$-based forecast.*

This 'range' scenario as described in Ulrich *et al*. (2017), searches for the minimum sum of differences between potential catches by stock under the 'min' and the 'max' scenarios within the $F_{MSY}$ ranges. The other 'range' scenarios could be computed in the future, for example scenarios minimizing the potential for discarding or maximizing fleets' revenue or profit.

## 3.6 Conclusions and perspectives

Without even discussing whether MSY is fully appropriate as an objective or whether a lower fishing mortality target like MEY (maximum economic yield) would be preferable, the difficulty to define and quantify this MSY objective remains a major impediment. For scientists, MSY is a sort of Holy Grail. Its quest is a noble cause, but it may never be found, and one may never know how it looks like and whether it has been truly reached. By nature, $F_{MSY}$ will always be varying even in a single-stock context, and it is inherently even less definable in a regional ecosystem context.

Without any doubt, the multiple biological and technical interactions that are well known and well quantified in many regions, like in the North Sea, cannot be ignored. Defining what is to be maximised (what is MSY) and whether it is a limit or a target is therefore not a scientific question alone. The fact that scientists argue against each other on the value and the appropriateness of MSY reflects this fuzzy border between science and policy (Mesnil, 2012). Therefore, MSY-based management requires first that this uncertain state of nature is understood and accepted. Only after can the necessary trade-offs be acknowledged, and the political choices be made.

Based on our scientific endeavours, we thus argued that the MSY concept needed modernisation and adaptation, not wholesale replacement (Kempf et al., 2016; Rindorf, Mumford, et al., 2017). Considering MSY as a multidimensional area rather than a point estimate is a new and pragmatic management approach. This creates a formal frame which prioritises the avoidance of risks ("staying away from where we do not want to be") to the achievement of a given optimum ("being where it is exactly best"), thus circumventing some of the most irresolvable definition questions while maintaining a productive ecosystem and viable fisheries (Degnbol, 2015).

Following these arguments, it has thus been proposed to define ranges of/around $F_{MSY}$ for each of the main stocks, estimating the range of fishing mortality which would provide for each stock some long-term yields close to the maximum possible while maintaining low risk to the biomass to fall below the acceptable threshold. This "Pretty Good Yield" approach is conceptually appealing to address the issues above, but it also requires the quantification of these ranges, and in particular of the upper value above $F_{MSY}$ point estimate. This one relies on an important subjective choice, which is the acceptable threshold of loss of yield compared to the maximum estimated.

(ICES, 2015b) developed one objective and generic approach in a single-stock concept, and used the subjective threshold of 5% loss of yield as the basis for defining MSY ranges. In an ecosystem context, this could be further refined to account for other criteria of sustainability. Within these ranges, it would be potentially possible to eliminate the combinations of single-stock fishing mortality that are mutually exclusive, i.e. which together would lead to undesirable or incompatible outcomes at the regional ecosystem scale.

With the FCube "range" approach, we have already provided a framework where some of these considerations can be taken into account. This could go some steps further, e.g. the MSY Fupper value could be lowered if other ecosystem considerations are included, or the MSY Flower could be increased if social criteria are considered (Rindorf, Dichmont, et al., 2017), Figure 3.9). Also political constraints may forbid the usage of values above $F_{MSY}$ in the longer run.

Thus, the $F_{MSY}$ ranges provide a flexible policy framework, potentially offering a buffer around a target for integrating the annual variations in productivity of the different stocks while defining clear limits for the undesirable states that should be avoided.

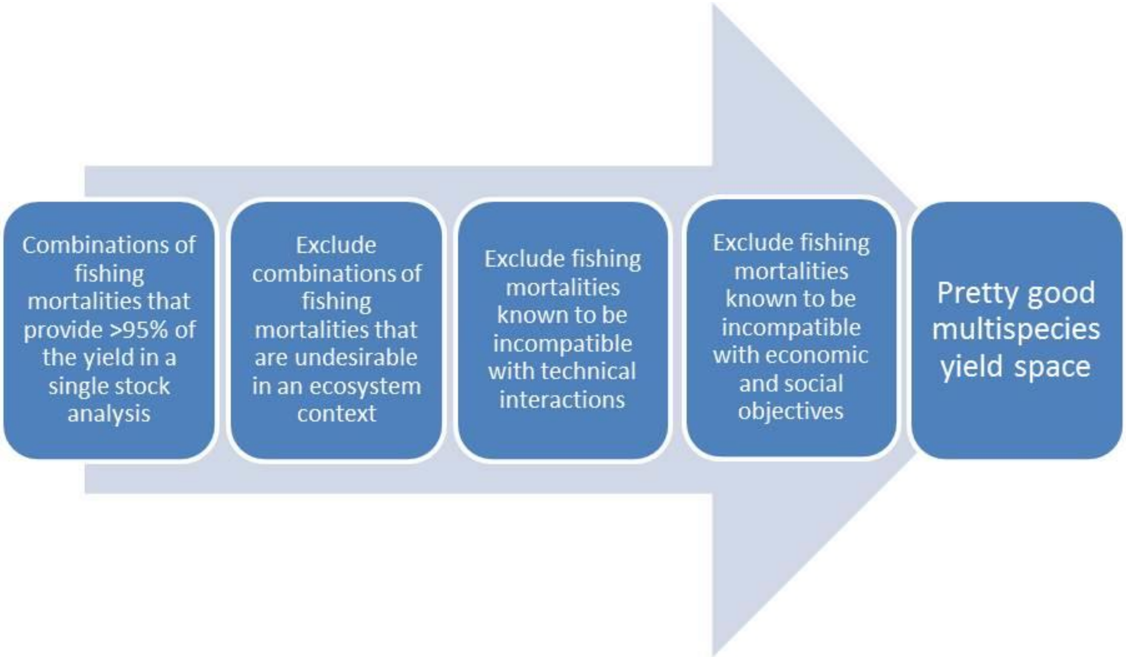



*Figure 3.9. The stages in defining pretty good multispecies yield. From (Rindorf et al., 2017)*

Following this approach, converting ecosystem objectives into corresponding single-stock $F_{MSY}$ ranges may lead to a narrower range, for example keeping 98% of maximum yield instead of 95%.

(ICES, 2015a) also pointed out clearly that F values above FMSY bear some costs in term of higher dependency on incoming year classes and higher variability in the advised catch opportunities (the occurrences where F has to be reduced because SSB is below MSY Btrigger will be more frequent). Fishing at the higher value of the range over a long period of time has negative consequences on fleets profitability and stocks biomass (although they might still remain precautionary with regards to Blim). It may therefore not be appropriate to fish systematically and blindly at the upper range.

One transparent option might be for example to choose $F_{MSY}$ as the default option for setting the annual fishing opportunities, and to allow for deviation from it within the range only on the basis of obvious and documented short-term conflicts, being of economic, ecological, social or political nature.

# 4 Technical and political options to reduce discards and unwanted bycatch

## 4.1 Introduction

European fisheries should operate without discards. After years of increasing evidence and societal pressure, this aim was clearly expressed in the beginning of the decade by both the European Union (EU) and other fishing nations in Europe, together with the overall intention to reduce the environmental impact of societies. In accordance with this, the landing obligation in the 2013 EU Common Fisheries Policy aims for a gradual elimination of discards of commercially exploited stocks on a case-by-case basis (EU, 2013).

However, this transition is not without economic and social costs in the short-term. Therefore, good intentions must be followed by effective implementation using the right methods and processes on a fishery specific basis. There is a need to recognise both the significant challenges and the potential benefits of the LO, and to make it understandable and legitimate across the whole supply chain, from stakeholders to consumers.

Given the ambition, maybe the "disruption", of this paradigm shift in fisheries management, it was understood that science could contribute in some ways to the successful implementation of the policy. Science cannot force political and behavioural changes, but science can gather and share useful knowledge to inform changes.

In this purpose, a research call (5 millions euros) was launched by the EU H2020 program in 2014 (call H2020-SFS-2014-2). I led a consortium of 31 partners and won the grant, with the maximum evaluation note received (15/15). This H2020 project I coordinated, called DiscardLess, started in early 2015 for a duration of 4 years (completion in March 2019), exactly accompanying the implementation phase of the LO (Figure 1.9 in Chapter 1). Considering the primary role that this project has played, both on my scientific carrier and on the knowledge base on discarding issues, I first present the main features and outcomes of this project in the next paragraph, before detailing some key scientific advancements.

### 4.1.1 Overview of the scientific knowledge gained during the H2020 DiscardLess project and of my personal contribution to it

DiscardLess was built as a multidisciplinary project (Figure 4.1) that aimed to

- UNDERSTAND the economic, biological and social drivers and impacts of discard
- PROPOSE a set of cost-effective Discard Mitigation Strategies: the DMS ToolBox

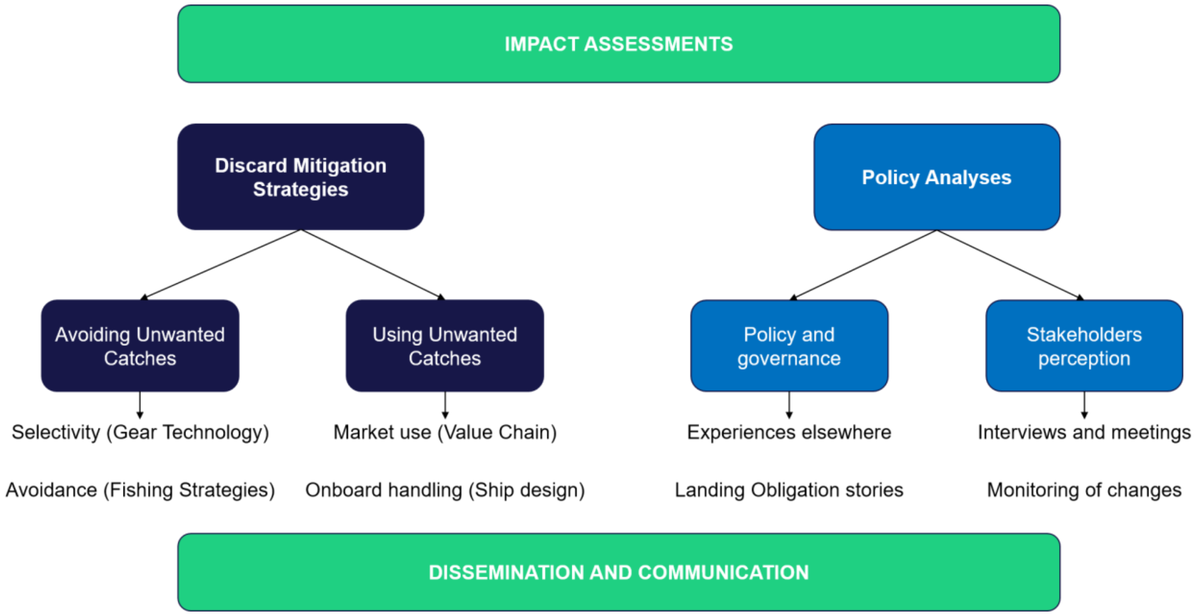



*Figure 4.1. Diagram of the H2020 DiscardLess project research themes*

Being the international coordinator of this project, I have been the leading force for building the approach, bringing the multidisciplinary team together, assigning tasks and responsibilities, allocating the budget and steering money use, writing the proposal and ensuring the overall project development and cohesion. Certainly I did of course not personally participate in every study and work package conducted in this project, and shall not report in this HDR thesis on works I did not directly contributed to. Nevertheless, the leadership itself, and the reporting obligations attached to it, gave me direct and immediate access to a huge knowledge basis developed by the project team, on topics I previously had little understanding on. This is best illustrated by the multiple facets described in the collaborative and open access book ("The European landing Obligation – reducing discards in complex multi-species and multi-jurisdictional fisheries" (Uhlmann et al., 2019, #27) I co-edited during the final year of the project, and published in time for the closing conference in January 2019.


*Figure 4.2 The Open Access book cover*

In addition to the comprehensive editor work, I was corresponding author of one chapter out of the 20 (James et al., 2019, #23), on one of my key research topic, electronic monitoring; I was major co-author in another one (Rihan et al., 2019,#26), on a chapter summarising the new challenges for evidence-based expertise that the LO policy imposed on the advisory bodies ICES and STECF; Finally I was minor co-author in a third chapter (Reid et al., 2019, #25) on the spatio-temporal mapping of discards hotspots to help inform avoidance strategies, a study where both the PhD student and the postdoc scientist I supervised at that time where themselves major contributors.

Beyond this direct contribution to scientific and technical achievements, as the project coordinator of this project I was also the one to give high priority and careful attention to secure the maximum impact of the project in the scientific, stakeholders' and general public domains. Many different dissemination and communication activities were held all along the project. An effort was made to secure an online record of every scientific activity undertaken in the project, in most cases with an associated DOI. In addition to flagging scientific papers, key reports and slides, the Discard Mitigation Strategies Toolbox was developed as a popular and open science repository on the DiscardLess website with interactive summaries of the work undertaken in the various scientific studies[16]. The other major channel of knowledge transfer occurred in the numerous meetings and workshops organised by or with the DiscardLess scientists, which allowed a continuous dialogue with the stakeholders and policy makers at local, national and EU levels.

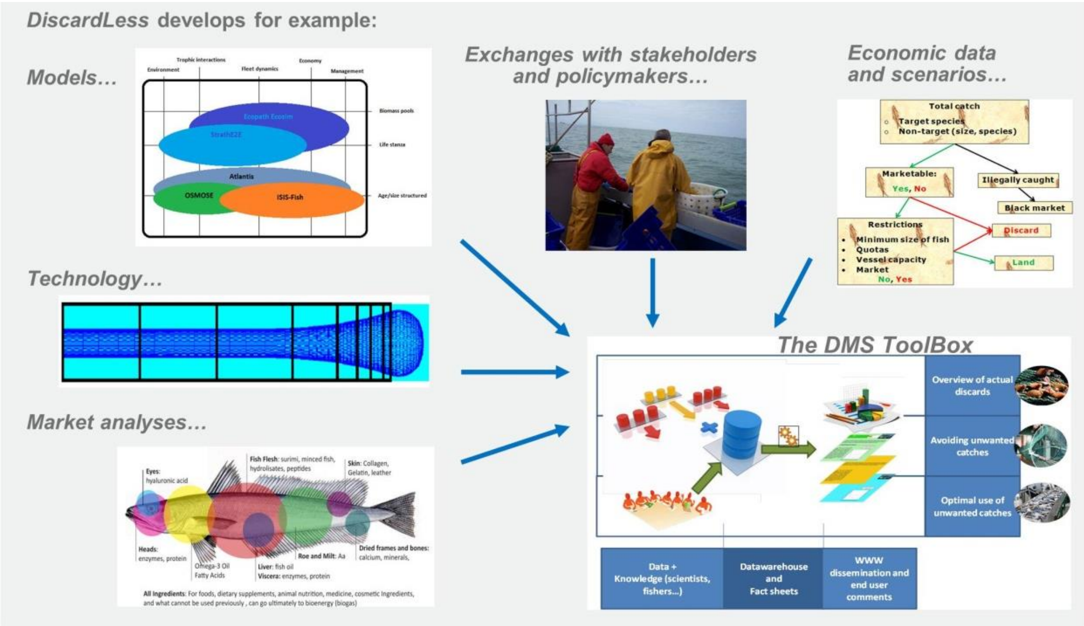



*Figure 4.3 Overview of the H2020 DiscardLess project. Extracted from the overview poster presented at ICES Annual Science Conference, 2015.*

### 4.1.2 Causes of discarding

As it has already been touched upon in the introduction of this thesis, the act of discarding is very rational, and the causes are simple. Thinking about how a fisher acts when the mixed catch is hauled onboard as the one pictured in Figure 1.3, an instantaneous decision must be made, for every single fish passing on the sorting band on the vessel's deck, to either to keep and bring back to shore, or reject and discard back to sea.

The decision to keep a fish requires both that it is legal and that it is profitable to do so (Figure 4.4):

[16] http://www.discardless.eu/tools

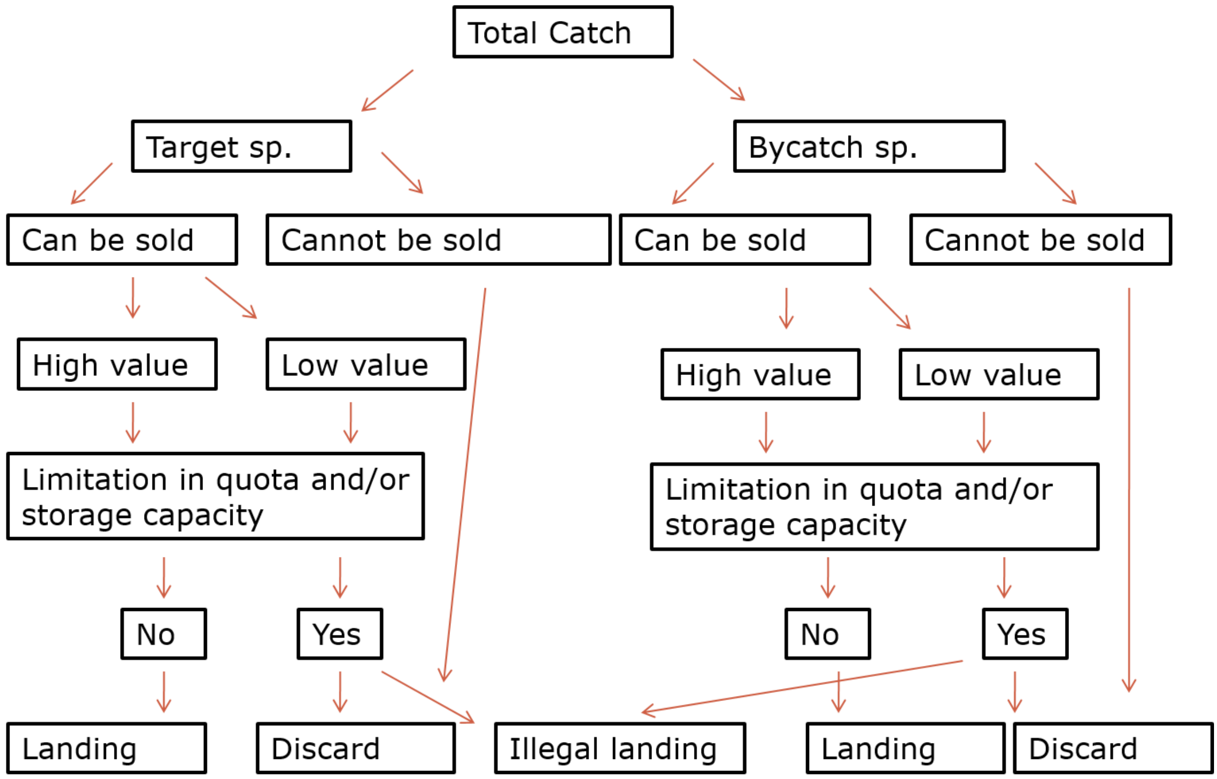



*Figure 4.4 decision tree for landing or discarding a fish caught.*

On this basis, the reasons for discarding are actually very few, and very generic. A catch is discarded either if:

- It is too small and falls below the minimum sizes imposed for most species of interest in EU (MCRS, Minimum Conservation Reference Size)
- It cannot be sold because of quota restriction (fish of legal size and marketable value but whose quota is exhausted or the fisher has no individual right for landing that species)
- Its marketable value is too low and the landing price will not cover the costs of handling and landing
- None of the above but the catch is unsuitable for landing, e.g. it has been damaged by the fishing net or by predators etc

A fifth cause, highgrading, is in reality a combination of the second and third cause. Highgrading means that fishers will retain some marketable catch onboard for some time, but if at some point during the fishing trip, storage capacity onboard becomes limiting and/or the catch volume allowed (quota) is constraining, the least valuable part of the stored catch can be discarded to give space to more valuable catches. This practice has been forbidden in the EU in 2008 but did not disappear (Batsleer et al., 2015).

These four causes are generic and apply with varying importance to any situation. For example, (Catchpole et al., 2014) allocated to a cause every discard recorded by UK onboard observers in the period 2002-2010, prior to the LO, and found that the four reasons were almost equally important overall, but with great variations across years, seasons, areas, species and fishing gear.

After understanding the causes, it is also important to understand the economic consequences of not discarding anymore, to figure out why it is so challenging to address this issue. Very much alike other environmental issues of e.g. pollution, pesticides and waste, discarding is a textbook example of a "necessary evil" practice, that no one would pretend is ethically acceptable but which is economically rationale and thus remains. Discarding exists because it is more cost-efficient to discard unwanted catches than to retain them onboard (Frangoudes & Guillen, 2015; Hoff et al., 2019). Discarding means both (i) Higher sale value (Selection of valuable species and sizes, and cleaner landings, where high valued catch component are not mixed with low valued components) and (ii) lower costs operating costs (slower filling of storage capacity implying fewer trips between fishing grounds and landing port, shorter sorting and handling time onboard, and thus less crew, and less infrastructures required at shore to handle unwanted catches). In addition to these direct economic consequences, discarding is also less expensive for society, requiring less control and monitoring onboard compared to controlling landing at shore only.

As such, unless cheap and effective solutions exist to avoid catching unwanted catches, it is economically rational and cost-efficient to maximise the quantity and value of the catch that can be sold, disregarding the bycatches whose environmental costs are externalised. The landing obligation was meant to change this, by internalising the bycatch costs and making fisheries accountable for them, assuming that they would then modify their business choices and make trade-offs between maximising the quantity and value of the catch that can be sold, and minimising the quantity of the catch that cannot be sold.

### 4.1.3 Choke species

In addition to this generic frame of intrinsic reasons why discarding naturally takes place in mixed fisheries, we need to focus on a situation particularly important in the EU, and explaining why discarding is even more important in our CFP fisheries than in similar mixed fisheries elsewhere: the issue of choke species, the species that "*strangulate*" the fishing. "*A choke species is a species for which the available quota is exhausted (long) before the quotas are exhausted of (some of) the other species that are caught together in a (mixed) fishery"* (Zimmermann et al., 2015). As was introduced in section 1.3, this issue is specifically prevalent in the EU because of the distribution of quota shares between (and within) Member States, using sharing keys which have not been updated since the 80s. Considering the high number of shares across numerous Member States, fishing types and species, there are many situations of potential mismatch between the fishing capacity and the fishing rights of individual fishers.

The discussion about choke species in EU Atlantic fisheries is not new and the wording was already mentioned in the early days of the mixed-fisheries analyses (Ulrich et al., 2011, #8). It though took a much wider importance under the landing obligation, when it shall in principle not be possible anymore to adjust fishing capacity with fishing rights by discarding the catch that cannot be landed. Discussions on "choke" thus emerged among managers and Member States in the first implementation years of the LO, trying to formalise and quantify the issue.

An important milestone in the understanding of the problem has been the identification of various types of possible choke situations, and the characterisation of their causes and responsibility. It has been recognized that choke issues can potentially occur in various situations, depending whether the shortage of quota is due to a poor status of a stock or a poor distribution of fishing rights. The Advisory Councils (NSAC, 2017b) developed a system for categorizing choke problems as follows:

- Category 1: Sufficient quota at Member State level—choke is due to distribution within the Member State such that a region, a fleet segment or an individual vessel does not have enough but this can be resolved by the Member State itself.
- Category 2: Sufficient quota at EU level, but insufficient quota at MS level—choke is due to a mis-match of catches and the distribution of quotas between Member States and can theoretically be resolved between themselves in a regional context.

- Category 3: Insufficient quota at EU level—choke is due to insufficient quota within the relevant sea basin to cover present catches or catch levels that can be realistically reduced, resulting in a total stop of fishing for a Member State or Member States.
- Category 4: Economic choking may occur at the vessel level when there is a considerable bycatch of a low value species and the boat is filled with fish that will not deliver a profit.

To quantify this further, one must also acknowledge that potential choke situations are in reality the summing up of individual situations of mismatch between fishing opportunities (quotas) and fishing capacity (catch potential) occurring, or not, at each fishing operation. In consequence, the "risk of choke" can be estimated at different scales: at the scale of the entire fish stock (as done in the ICES mixed fisheries advice, cf Figure 3.2 in chapter 3); at the scale of a Member State comparing its national quota with its historical landings (cf example Figure 1.6 in Chapter 1); at the scale of a fishing fleet assuming some standard quota distribution sharing agreements within a Member State; or at the scale of the individual fisher.

As an illustration, we investigated in Mortensen et al. (2018, #30) how a Danish fisher operates in its daily choice of fishing ground and fishing gear depending on how much individual quota of cod and saithe he had at disposal, and how he constantly balances between either leasing additional quota or moving away depending on market and quota prices (Figure 4.5).

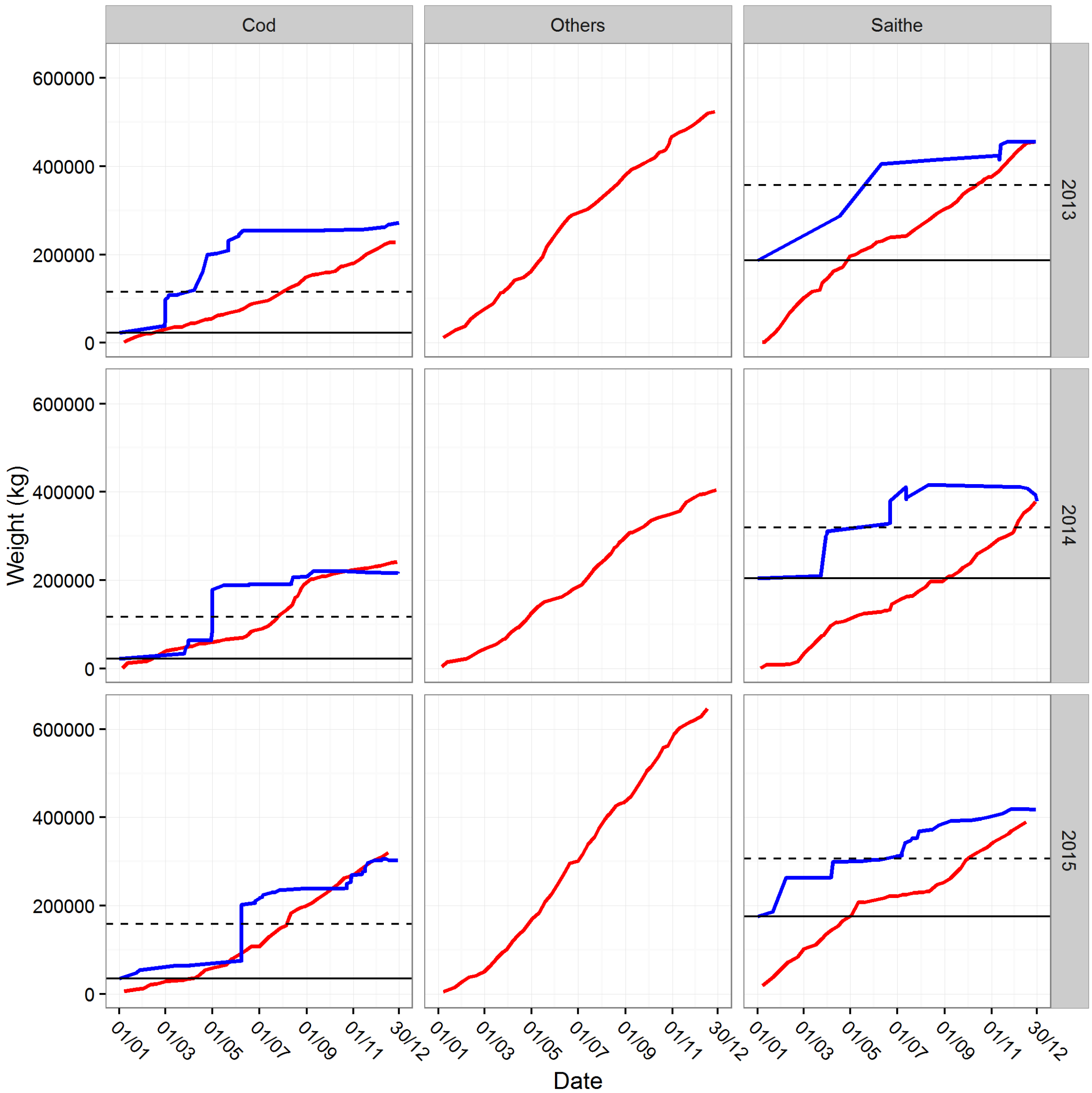



*Figure 4.5 Plot showing the landing (red) and quota (blue) development of saithe, cod and other species (OTH) in the years 2013, 2014 and 2015. Horizontal lines indicates the initial quota (solid) and initial quota including transferred quota from partner vessel (dashed). Source Figure 1 in Mortensen et al., 2018)*

Three simultaneous studies performed for the European Parliament in 2018 revealed that the "choke" issue was most acute in the North Western Waters around the British Isles and Ireland (Rihan, 2018), but is also observed in the North Sea (Ulrich, 2018, #1) and SWW (Prellezo et al., 2018).

This risk of "choke" situation can be considered to be the main barrier against the successful implementation of the landing obligation, as it roots back to historical sharing agreements in the early days of the CFP (cf. Chapter 1), and requires more than simple technical adjustments in the gears to be solved.

,

## 4.2 Options to reduce discards

As explained in Figure 4.3, the DiscardLess project focused very much on investigating a diversity of options to reduce discards, either by avoiding unwanted catches through technological (gear design) or tactical (where and when to fish), or by better utilising the unwanted catches that cannot be avoided. The global overview of the analyses investigated is displayed in Figure 4.6.

Only avoidance strategies are discussed here below; for information about utilisation strategies, see http://discardless.eu.

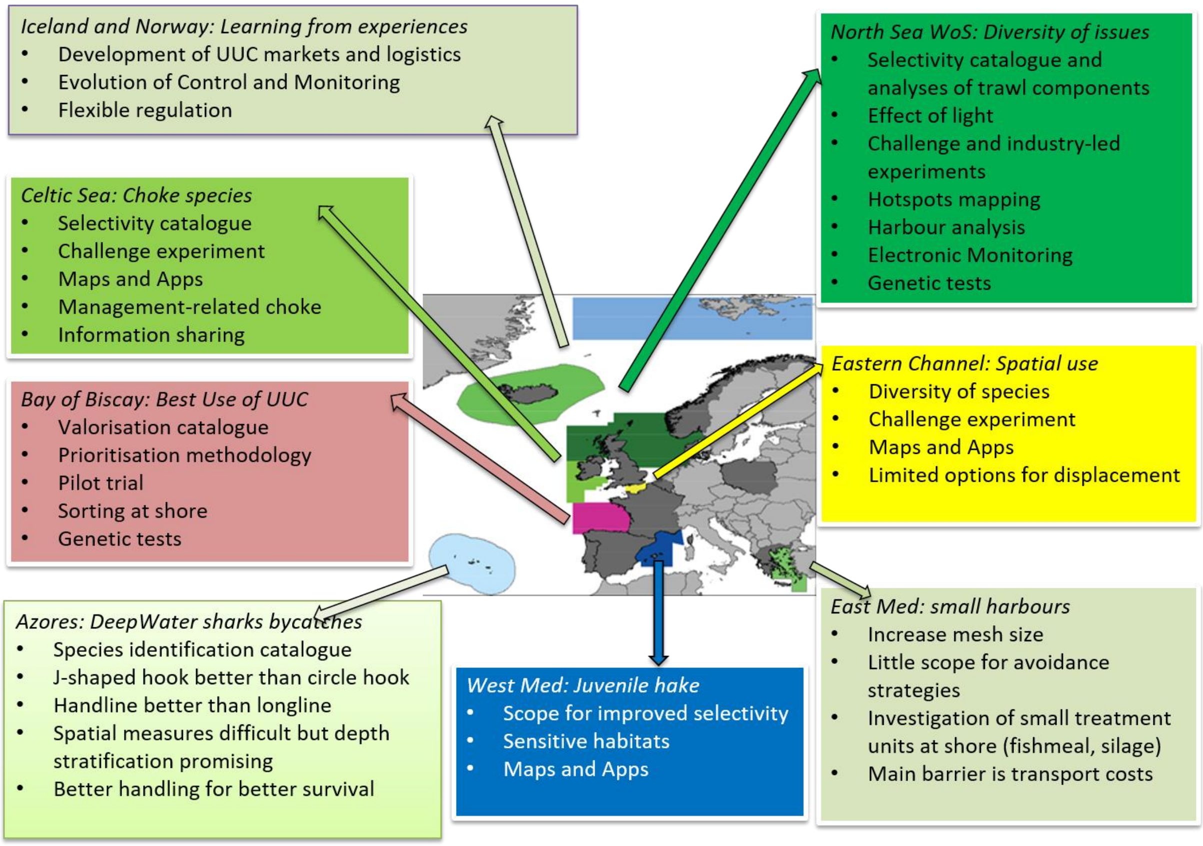



*Figure 4.6. Summary picture 2: Overview of the discard mitigation strategies investigated in the various case studies of DiscardLess. UUC Unavoidable Unwanted Catches*

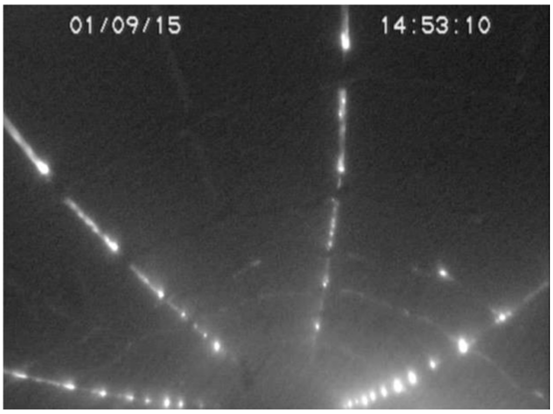
### 4.2.1 Technological options: changing gear design to increase selectivity

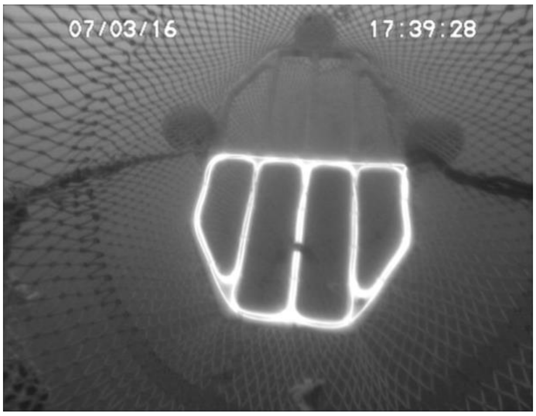
Gear technology is an old research topic, but the LO brought a renewed interest on it, and the recent years have seen several initiatives to both re-mobilise ancient knowledge from older, and sometimes unpublished, studies, and to design and investigate novel approaches involving modern technology.

DiscardLess' own contribution is summarised in the book chapter by (O'Neill et al., 2019). Not having been a direct contributor to this I do not bring detailed results here, but only an overview of outcomes and state of knowledge. Among others, DiscardLess translated the results of more than 90 existing trials in a standardised intuitive format[17] to facilitate the sharing of existing knowledge on selective devices. Based on in-depth quantitative meta-analyses, a simple booklet was also published to explain the role played by other components of a trawl (incl. opening line, ropes, cables, doors etc) in the catching process,

[17] http://www.discardless.eu/selectivity_manual

influencing the swimming behaviour of fish species and not least their vertical distribution and thus their likelihood to escape the trawl. Finally, DiscardLess performed several trials using light to try to enhance the escape behaviour of unwanted fish. Preliminary results showed that some species can potentially be directed upwards or downwards within a trawl, but there are still a lot of variability and more understanding is needed.




### 4.2.2 Tactical options: changing where and when to fish

Different species have different spatial distribution, and it is relatively easy to plot average patterns of co-occurrence of commonly caught species, both from fisheries landings data and from scientific survey data(Figure 4.7).

Intuitively, there should thus be scope for changing catch composition and avoiding catching unwanted species by changing fishing tactics (depth, location and time of day of the fishing). The possible approaches are generally local in nature, e.g. fishing deeper in the Celtic Sea, or switching away from inshore zones in the English Channel.

Mapping potential discard hotspots is clearly a topic where science can significantly assist, by performing advanced spatio-temporal analyses of fish distribution. This was extensively studied in DiscardLess in a number of sea basins, as summarised in the book chapter by Reid et al. (2019, #25). Observer, survey and fishery data were combined to define "hot spots" of unwanted catches, at a fine spatio-temporal scale. These include hots spots of "choke" species, and of juvenile fish. Easy access maps and apps were also created[18].

[18] http://www.discardless.eu/discard_maps

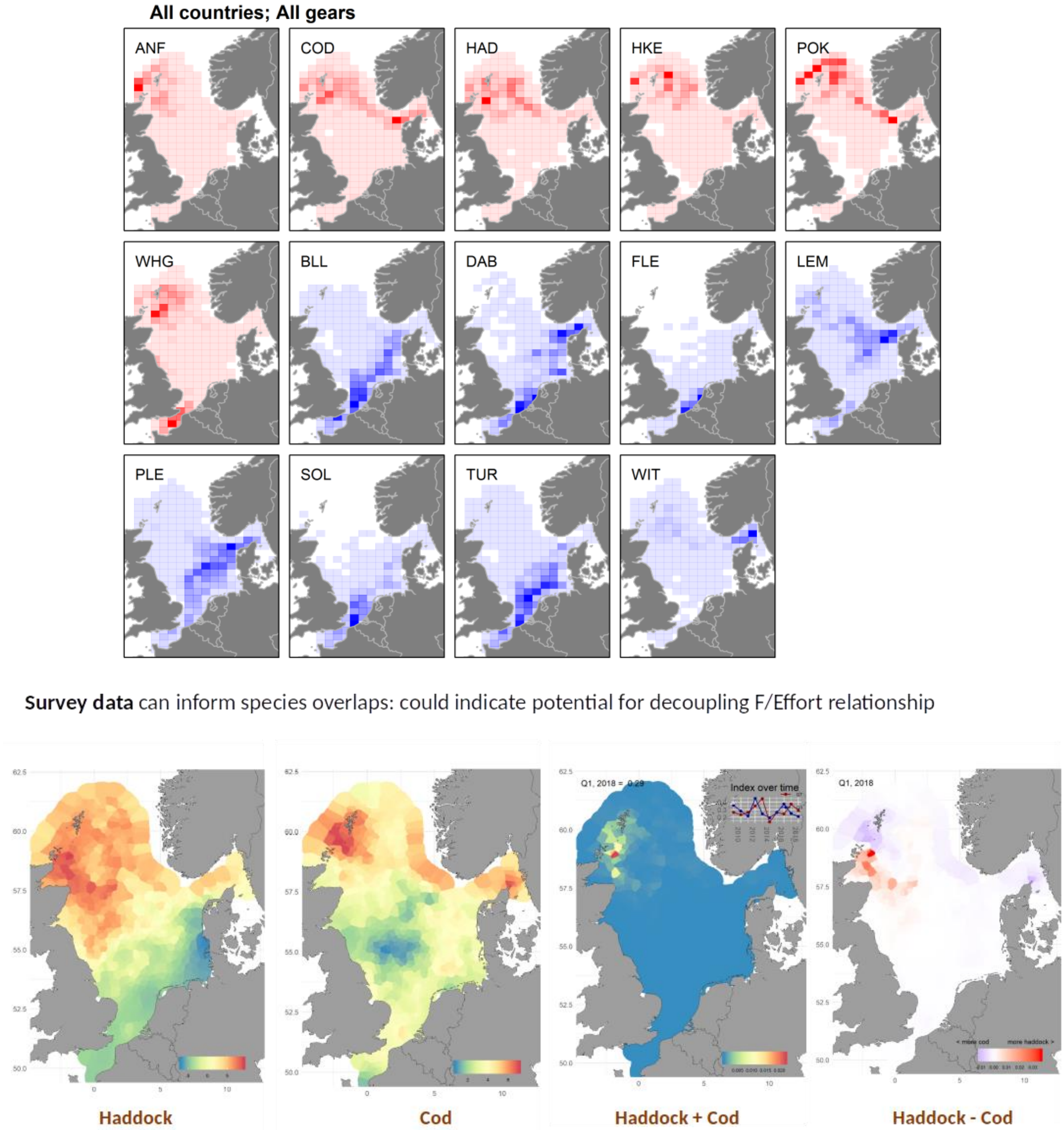



*Figure 4.7 Stock distribution from commercial catches (top:. Roundfish gadoid species in red, flatfish in blue) Source ICES WGMIXFISH and modelled survey data (bottom) (P. Dolder, unpublished) .*

However, the knowledge gained through the numerous studies also showed the limits of the approach. One major gap is the absence of data at the required scale to analysis this properly. Avoidance strategies are deployed by commercial fishers at the scale of the fishing operation, but available data at that scale are limited, especially regarding the unwanted and discarded component of the catch. Given the very low coverage of scientific observers in EU (less than 1% of trips have an observer onboard), such detailed knowledge is largely missing and hotspots maps can only be performed as average patterns, for example pulling together several years of observations (Robert et al., 2019). As a consequence, it is easier to predict areas and times with a low discard probability than high risk areas.

To overcome these limitations in spatial knowlegde, my post-doc student Lars O. Mortensen and my PhD student Kristian S. Plet-Hansen both worked with some individual Danish fishers and got privileged access to detailed information and knowledge, which revealed interesting patterns. In particular, (Plet-Hansen et al., 2018, #28) got access to a completely new dataset from commercial fisheries, never used for science before. That dataset, collected for the purpose of full traceability including weighting of fish at sea (and not at the auction when landed) provide knowledge on landed fish with high spatio-temporal resolution (haul-by-haul) but with the addition of detailed knowledge on the size distribution. Combined with FDF data providing additional information on discards, Kristian was able to perform new fine-scale mapping on the location of small fish from commercial data (and not survey data only), which could potentially inform fishers on spatial avoidance strategies without reducing profit (Kristian S Plet-Hansen et al., 2020, #19). For example, it was possible to generate raster maps of vessels' per haul value in euros against discards hot spots (Figure 4.8). The map shows that the discard hotspot areas often coincide with high value hauls but importantly, there are also other high value areas without such high discards levels.

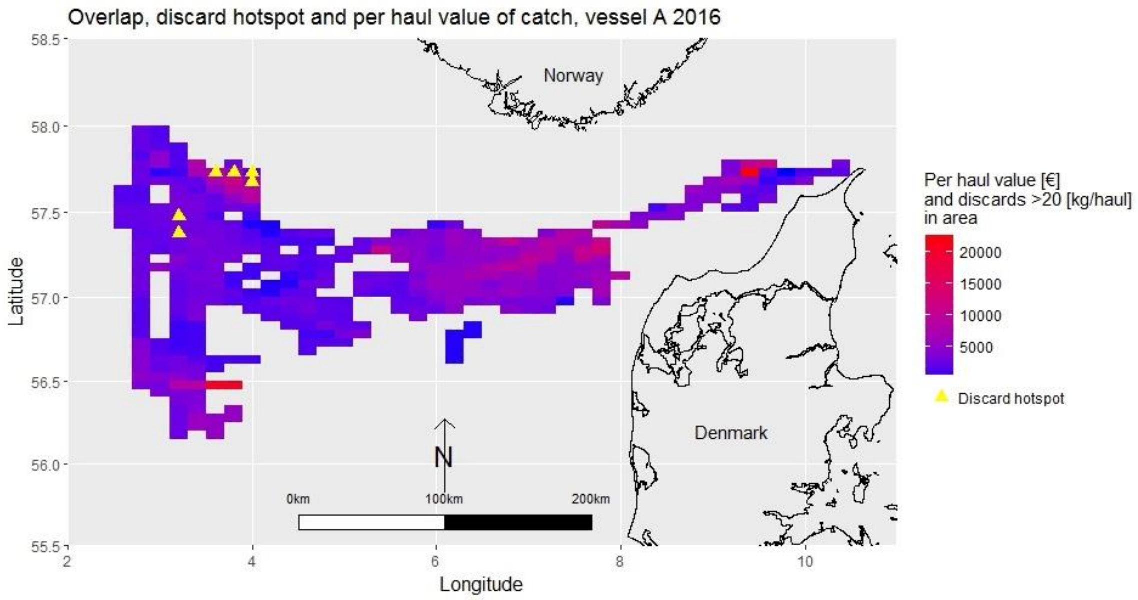



*Figure 4.8 Gridded map of the landing value per haul for a single Danish trawler in 2016. The red colour represents the greatest value per haul. The yellow triangles represent the areas of high discard volumes. Picture by K. S. Plet-Hansen in Reid et al. (2019), later published in a different display form in (Calderwood et al., 2020)*

In a different study, (Mortensen et al., 2018, #30) showed that avoidance behaviour was difficult to detect even with detailed fisheries data, which was explained by avoidance taking primarily place through very fine-scale tactical choices rather than large displacements. For example, given the high observed patchiness of saithe compared to cod, the skipper explained that the tactic employed if large catches of saithe were encountered, was actually to exactly continue along a transect, deploying the gear where it was hauled in and subsequently continuing along the current heading, expecting lower catch rates just behind the patch…. Such an informed decision would be impossible to detect if not told, even with full information. Another example of fine-scale decision was that, while the skipper was able to identify specific areas of a few square nautical miles where it is possible to avoid saithe and cod in the catches, he also pointed out that the abundance of other valuable species in these area would be variable, thus requiring daily trade-offs to be made between a high probability of making a profitable haul and a high risk of catching unwanted species.

## 4.3 Overcoming the barriers to discards reduction through results-based management and fully documented fisheries

### 4.3.1 Background

As introduced in section 1.1.3, there are a number of political, socio-cultural and economic factors that play against achieving discard reduction, because of a poor alignment between the fishers' individual incentives and the societal conservation goals. Even when conducted in collaborative projects with the fishing industry, selectivity trials do often not lead to obvious selectivity improvements. A key issue for the future is thus to move away from "tunnel vision" (Degnbol et al., 2006) and try to better align top-down and bottom-up incentives in a more "win-win" approach promoting responsible fishing (Eliasen et al., 2019; Feekings et al., 2019, #21-22).

Over the last years of my carrier at DTU Aqua, I engaged significantly in this topic. Working in Denmark was a great "playground" for this, because the fisheries and managers in this country have long been willing to engage into a front-running experiment with Fully Documented Fisheries, leading to great social knowledge and new biological data.

It all started around the mid-2000s when a poor status of the North Sea cod led to major reductions in the TAC (-80% in 4 years !). But instead of reducing fishing mortality, over quota catches were rather discarded or landed on the black market. As a result of total catches being thus poorly monitored and quantified, the quality and reliability of the stock assessment decreased, leading in turn to even lower TAC advice the following year (Ulrich et al., 2011; Kraak et al., 2013, #8, 39).

This situation of poor control and monitoring of cod catches raised political awareness. In 2008, the EU launched a new cod management plan (EC, 2008b), based on drastic reductions of fishing effort aligned on the reduction in cod fishing mortality needed to rebuild the stocks (not only in the North Sea, but equally in Kattegat, Irish Sea and West of Scotland). But that plan also opened up for options to get exempted from effort reductions, provided that low cod mortality could be demonstrated. This paved the way for the earliest initiative on a new approach for managing cod fisheries, launched by Denmark in 2008. The Danish Minister of Fisheries presented a comprehensive proposal to the EU Council of Ministers, stating that all catches and not only landings should be counted in the quota[19]. This was meant to break the negative socio-ecological feedback loop (Österblom et al., 2011) and restore the basis for reliable assessment and management of the depleted stocks. This started the first trial of Catch Quota Management (CQM) scheme.

CQM is an implementation in practice of what is generically referred as Results-Based Management (RBM), an approach to delegate specific management and documentation responsibilities to resource users (Nielsen et al., 2015, 2018). A requirement for entering into such a scheme is thus that the entire catch is accurately reported, and can be

---

19 https://en.mfvm.dk/fileadmin/user_upload/ENGLISH_FVM.DK/Themes/Yield_of_fish/Paving_the_way_for_a_New_Common_Fisheries_Policy_revised_2009.pdf

documented and verified; this is what has been called Fully Documented Fisheries (FDF). To achieve this, the technology of remote electronic monitoring (EM) was already emerging at that time, with first developments taking place in Western Canada. In brief, a standard EM system consists of a GPS (Global Positioning System), a hydraulic pressure sensor, a photoelectric drum rotation (winch) sensor and up to 8 cameras providing an overhead view of the aft deck and closer views of the fish handling and discard chute areas (Figure 4.9). .

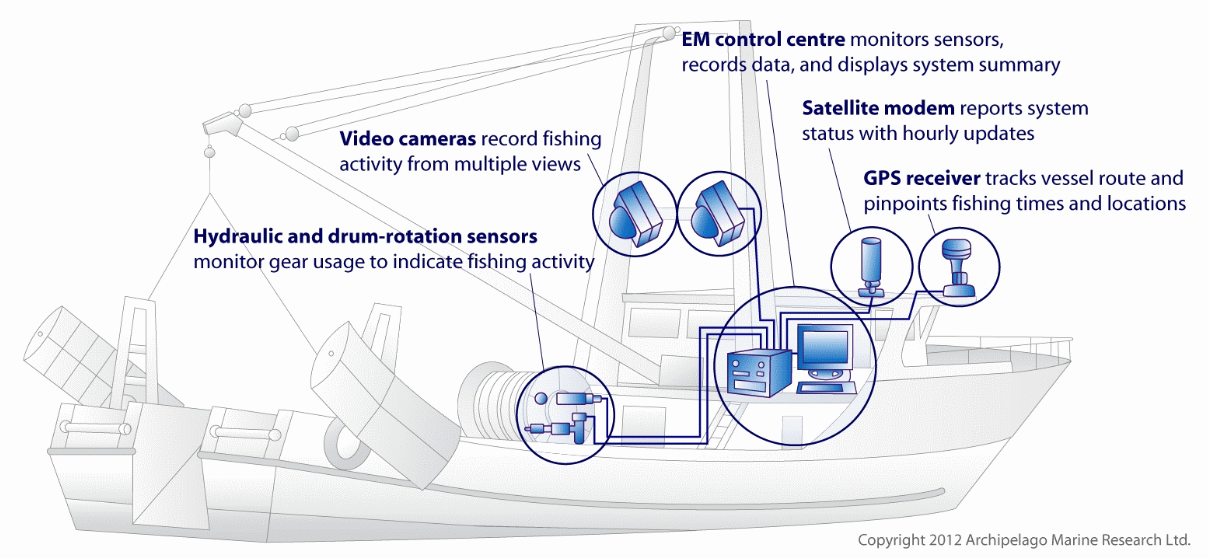



*Figure 4.9. Overview of a standard remote electronic monitoring system setup. Courtesy of Archipelago Marine Research Ltd.*

A first feasibility study took place in Denmark in 2008, the first of its kind in Europe. Building on its encouraging results, the paradigm shift towards CQM and FDF gained rapid political support at the regional North Sea level, and was endorsed by a Joint Statement signed in October 2009 by fishing authorities in Denmark, UK and Germany who agreed to explore the scope for a voluntary and incentive-driven management scheme[18]. This translated almost immediately into fundamental changes in the annual TACs and quota regulation for cod. In early 2010 the European Union officially made provisions for a CQM scheme for the quotas of cod in the North Sea, Skagerrak and Eastern Channel (Council Regulation (EU) No. 219/2010), allowing participating vessels to make additional catches within an overall limit of an additional 5 % (12% after 2011) of the quota allocated to the Member State, provided that:

• the vessel makes use of closed circuit television cameras (CCTV), associated to a system of sensors, that record all fishing and processing activities on board the vessel,

• all catches of cod with that vessel are counted against the quota, including those fish below the minimum landing size,

• the additional catches are limited to 30 % of the normal catch limit applicable to such a vessel.

Following this, several voluntary schemes took place in the supportive Member States (van Helmond et al., 2020, #17), and were renewed annually until 2018, when the 2008 cod management plan was terminated and repealled by the provisions under the North Sea

MAP (EU, 2018) and the landing obligation. To give an order of magnitude, in 2012, FDF fisheries represented a small proportion of the total fishery in the North Sea and Skagerrak (ICES subdivisions IV and IIIaN) (5.6% of total effort), but they represented a large proportion of the cod catches (36%). Most of the FDF fisheries occurred in the main cod gear (otter trawls/seines of ≥120 mm mesh size, TR1), where they represented almost 30% of the effort and 45% of the cod catches. Among the countries fishing in the area, the FDF share was largest for Denmark, where it represented up to 48% of TR1 effort, and 58% of TR1 cod catches (Ulrich et al., 2015, #5).

These cod-focused trials were followed by other types of FDF trials, extending to other species or with different purposes including the monitoring of cetaceans bycatch in some small-scale gillnet fisheries. (James et al., 2019; van Helmond et al., 2020, #17-23).

### 4.3.2 Observed changes in fishers' behaviour engaged in FDF trials

I had not been personally involved in the first Danish FDF trials, neither on the technical side nor in their early management application. It is only after 2013 that I gained interest in the subject, initially guided by the feeling that these detailed haul-by-haul data collected by fishers and video viewers at the ministry might have some scientific value and could be used for other purposes than management alone. I performed an extended analysis of the first five years of reliable data (2010-2014; Ulrich et al., 2015, #5). Beyond showing that discard levels in FDF vessels were on average much lower than the levels observed in the corresponding non-FDF fisheries, I made two striking « social observations », which definitively convinced me of the power of awareness and of smart incentives in a well designed results-based approach.

The first observation was about the will to report. While the reporting of discards in logbooks for all species above 50 kg had been in principle compulsory for all EU vessels since 2011, there was a striking contrast regarding compliance to this legal obligation : All FDF vessels reported discards in logbooks ; and they were almost the only ones to do so (Figure 4.10).

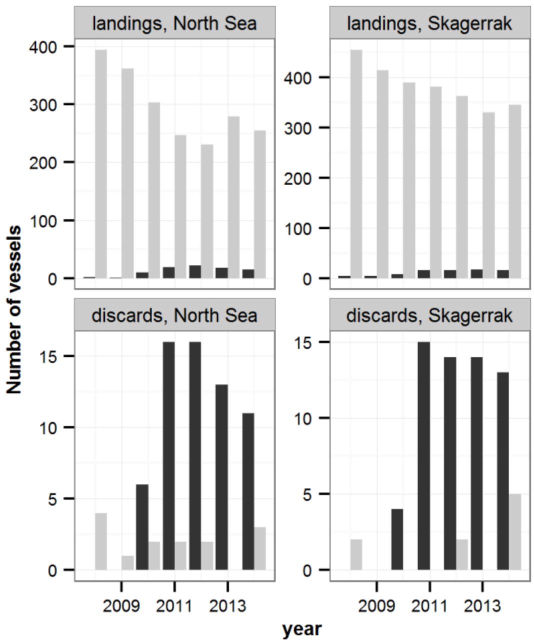



*Figure 4.10. Coverage in cod information available in logbooks regarding number of vessels for FDF vessels (black) vs. non FDF vessels (grey), by year (2008-2014, x-axis), area (vertical panels) and catch type (landings in top line panels, discards in bottom line panels). Figure 2 in (Ulrich et al., 2015, #5).*

The second observation was about the power of awareness and sense of accountability to change behaviour, but also the differences between individual fishers reasonably « alike » in theory but reacting very differently to the same regulation (Figure 4.11).

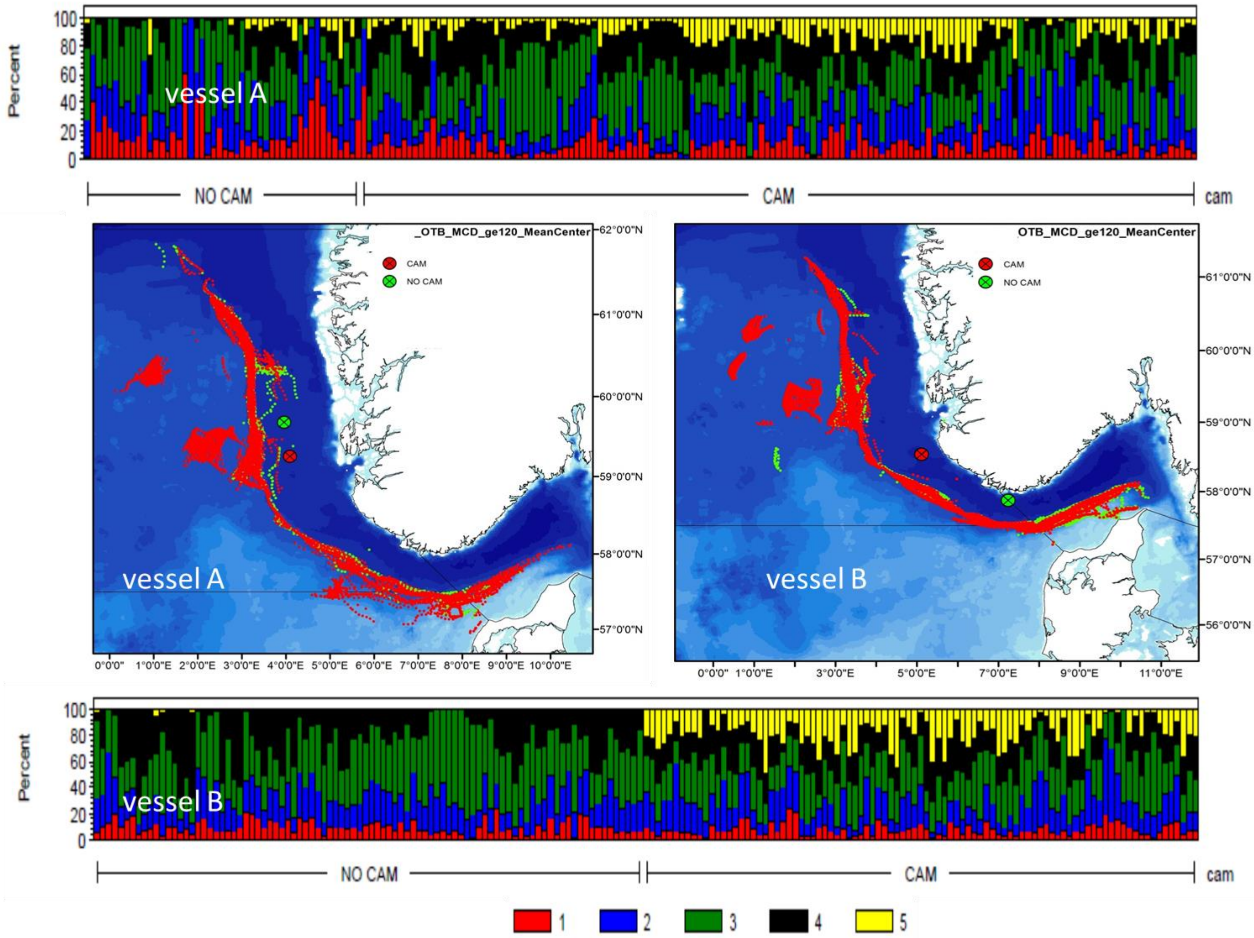



*Figure 4.11 changes in behaviour before (« NO CAM ») and after (« CAM ») the start of the FDF trial for two individual participating vessels, A and B. Column bars plots : proportion landed of cod catches by commercial size class (from 1, large cod, to 5, small cod) ; Maps : VMS plots of fishing effort distribution, with the center of gravity displayed as crossed dot. From Ulrich et al. 2013, presentation to ICES Annual Science Conference).*

On the figure above, the vessel A did not change radically its fishing pattern after entering the FDF trial, although he showed more regularity in its landing of small cod (in yellow). In contrast, vessel B showed a major shift in landing pattern. Keeping in mind that this vessel had received a 30% increase in its individual quota, he started to land small (but legal sized) cod in substantial proportion ; it can reasonably be assumed that most of this was discarded and highgraded before. Interestingly, this vessel also started spending more time further north in the norwegian waters, obviously with increased travelling costs, indicating some global changes in the daily tactical choices of where to fish, which are largely determined by balancing costs, catch value and constraining quotas (Mortensen et al. (2018, #30). This observation demonstrate that in this case, the skipper knew how to reduce discards but just did not have the proper incentives for doing so before.

These results presented in Ulrich et al. (2015, #5) can be considered as a positive and successful demonstration of the FDF and RBM concepts, having (i) reduced discards without additional technical rules, (ii) improved compliance to registering all catches in logbooks and (iii) enhanced controllability of the TAC management system.

After this study, I got really interested into understanding further the social incentives created by results-based management, especially in the context of the EU landing obligation that was being incrementally implemented from 2015 on. Could the subtle balance between carrot and stick, between freedom of action and obligation of documentation, between top-down and bottom-up, help reach the better alignment between individual incentives and societal goals we are looking for ? In this quest I had the chance to supervise both a post-doc student, Lars O. Mortensen (2015-2017) and a master (2015-2016), then PhD (2016-2019) student Kristian S. Plet-Hansen on this subject. Our collaboration was very productive, with 12 articles published together. Both worked in the frame of fully documented fisheries and results-based management, but with different approaches. Lars worked primarily on technical options for discards reduction using gear-based approaches, while Kristian worked on tactical options using spatial avoidance strategies. The main outcomes of this collaboration are described the next paragraph.

### 4.3.3 Results-based management and the landing obligation

In addition to his work already presented in section 4.2.2. above (Mortensen et al., 2018, #30), postdoc Lars O. Mortensen mainly worked on a national FDF project, called MINIDISC, financed by the EU EMFF. The aim was to experiment with a free gear choice experiment, whether fishers would manage to reduce discards without reducing profit, using any technical mean they wish (Mortensen et al., 2017, #34). This trial incarnates thus the original spirit of the landing obligation, where fishers are only accountable of their impact (the total mortality they induce on all species) but not of the way they produce it, provided that the stiff technical regulation in place since 1998 would be made less constraining in terms of the list and specifications of authorised gears (Eliasen et al., 2019, #21)[20]. To make the analogy with traffic regulation, RBM corresponds to speed limit on the road, where the only criteria to be controlled is whether the driver respect the limit, not whether he reaches that speed limit with a 2CV or a ferrari !

In this aim, a 6-months 'unrestricted gear' trial was performed in Denmark in 2015. Twelve trawlers of different size, rigging, fishing area and target species participated voluntarily and tested their own solutions to reduce unwanted bycatch and/or choke species, while maintaining their profitability. The only requirement was, again, fully documented fishery (FDF), including electronic monitoring, self-estimation of discards and haul-by-haul catch documentation (Mortensen, Ulrich, Olesen, et al., 2017, #35). Fishers' participation in the trial was partly incentivized through the allocation of additional quota. Fishers used twinned standard and test gears whenever possible (i.e. if they were rigged for twin trawls), or switched gear sequentially otherwise (eg.g for seiners).

The participating fishers tested different options depending on their fishery and the type of issues they faced individually, and adjusted their test fishery over time through incremental small steps. A total of 1497 hauls were video-analysed for landings, discards and discard ratio (discard-to-catch ratio), along with species composition and temporal trends Figure 4.12.

[20] NB the EU regulation on technical measures has finally been revised in late 2019 (Regulation (EU) 2019/1241, after three years of trilogue negotiations, and thus posterior to the conducting of the studies and trials described here.

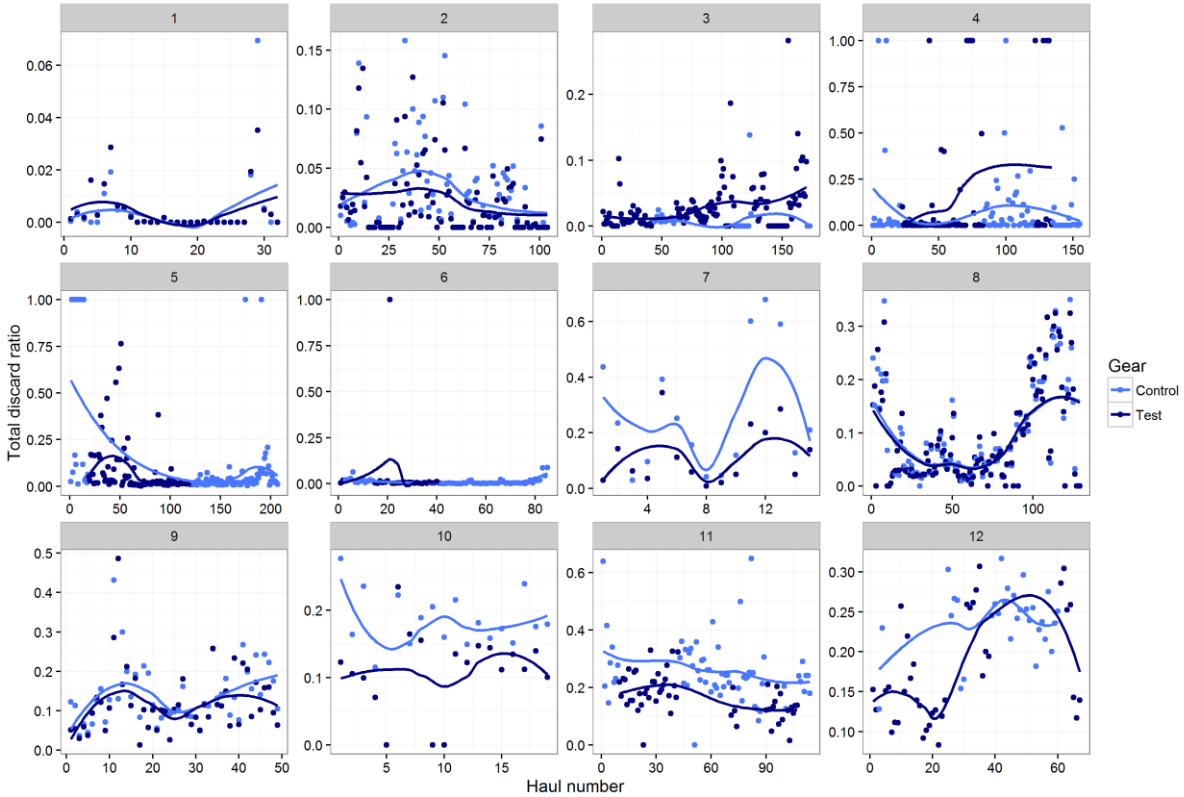



*Figure 4.12. Temporal changes in the discard ratio of each vessel (vessel numbers in grey) and type of fishery per haul. Light colour indicates control fishery, while dark colour indicates test fishery. Discard ratio was calculated as the total discard per haul divided by the total catch per haul. Curves are smooth splines using a local polynomial regression fitting (LOESS). (Figure 4 in Mortensen et al., 2017).*

Overall, nine vessels reduced discard ratio in the test fishery, one showed no difference between test and control fishery, while two vessels displayed an increase in discard ratio. The catch compositions were also significantly different, with fewer predicted "choke species" occurring in the test fisheries and a more valuable size composition. Ultimately, despite smaller landings in multiple vessels, no vessel showed reduction in value-per-unit-effort (VPUE) and one Baltic vessel significantly increased the VPUE. No temporal trends in discard ratio were noted.

This trial showed that relaxing technical regulations combined with proper incentives has a potential to provide some flexibility to cope with the landing obligation, where unwanted catches could be reduced to some extent without negative effects on economic viability. Some practical implementation challenges were nevertheless encountered, which were discussed in the article in the perspective of implementing results-based management at full scale.

On a sligtly different topic, PhD student Kristian S. Plet-Hansen conducted his PhD in the frame of the H2020 DiscardLess project, and touched on various aspects of fully documented fisheries, electronic monitoring and landing obligation (Kristian Schreiber Plet-Hansen, 2020). His analytical work on fine-scale spatial data was already presented in section 4.2.2 above, but Kristian also investigated key aspects related to the functioning of EM, both in terms of technology and design (James et al., 2019; Kristian S. Plet-Hansen et al., 2019, #23-24), but also in terms of fishers' acceptance and incentives (Kristian S. Plet-Hansen et al., 2017; van Helmond et al., 2020, #17-33).

### 4.3.4 Conclusions

The conclusion of all these numerous studies on electronic monitoring is that EM as a monitoring tool has a range of solid strengths and has the opportunity to be a powerful tool for the monitoring of a wide range of different types of fisheries. Electronic monitoring can be used to fully document a fishery or be integrated with existing data collection programmes, for management and compliance purposes or scientific data collection.

Nevertheless, EM and other MCS (Monitoring, Control and Surveillance) technology are only a tool and will not solve the discard issue alone. The crucial elements for the successful implementation of the LO remain the compliance from the fishing industry. If the industry support remains low, there will always be ways to render MCS programs ineffective, especially if their coverage is low. Moving forward, this means that MCS is a necessary but insufficient tool for the successful reduction of discards, and MCS programs must thus be integrated into a broad mind shift within the fisheries and seafood sectors towards better accountancy, transparency and sustainability, and/or implemented with a high level of coverage. In other words, there is a need continue changing the association of EM from being a "Big Brother" perspective to "giving the responsibility back to the fishing industry" in a results-based approach, exactly along the lines of what we experimented with in Denmark.

# 5 Perspectives: The Common Fishery Policy: new challenges, ways forward and the role of science

This being an HDR thesis, I should normally discuss at this stage my carrier perspectives in terms of future research projects. However, my situation is a bit special here. I left my scientific carrier in Denmark, and I am now Deputy Head of Science at Ifremer. This means that I do not conduct research myself anymore, and will not supervise PhD students in the near future. Getting this HDR is diploma is though important for the sake of my new level of responsibilities, also formalising the equivalence of the professor title I had passed in Denmark in 2014.

It does not therefore make much sense here to propose a vision for a research project. Rather, I choose to discuss some future perspectives for the conservation pillar of the Common Fisheries Policy and its mixed fisheries (here not specifically speaking about the North Sea only, but in more general terms), with an emphasis on the role that fisheries science should play in this landscape.

Part of my reflexions below come from the latest study I performed for the European Parliament. During summer 2019, just before my move to France and as my last major contribution at DTU Aqua, I co-led a synthesis study tendered by the outgoing PECH Committee of the European Parliament (Aranda et al., 2019, #20). The EP requested an overview of the current situation, achievements and remaining challenges in European CFP, meant to the attention of the newly elected PECH Committee and its many new members (MEPs) following the 2019 European elections. I wrote the first chapter dedicated to fisheries management and the conservation pillar of the CFP, together with my Portuguese colleague in STECF and in DiscardLess Lisa Borges. Other authors prepared the two following chapters on the Common Market Organisation (CMO) of the EU seafood trade, and on the External dimension (management of EU fleets operating outside of EU waters, in areas regulated by Regional Fisheries Management Organisations RFMOs).

This present chapter build to a large extent on this EP study chapter, distinguishing between policy challenges (section 5.1) and biological/ecological challenges (section 5.2). Though, for each of the reflexion points, I added some specific view on the science needs to progress along the challenges and on how science can help move forward.

## 5.1 Policy challenges

The 2013 CFP relies on ambitious objectives, aiming for sustainability while creating a flexible frame with less rigid top-down and one-size-fits-all regulations. The landing obligation, the regional multiannual plans, the new technical measures regulations… all are still rather new policies, based on fundamentally different management paradigms from what was in place in the previous CFPs. It is thus yet to be seen whether this will improve management and decision making, and will lead to positive outcomes in terms of stock status, fleets profitability and coastal livelihood. Considering also the increasing role of the European Parliament in decision making, the complex institutional trilogues, and the new roles of regional groups of Member States in a more decentralised CFP, this all bring new policy challenges to EU fisheries management. The developments and progresses achieved along these various topics in the next few years will be determinant in shaping the future CFP.

### 5.1.1 Brexit

#### *5.1.1.1 The challenge*

Notwithstanding the above, it seems timely to rank Brexit as the very first challenge for the Common Fishery Policy. Brexit is, to no one's surprise, a seism for European fisheries management. At the time of writing this HDR, end of October 2020 and some days only from the announced deadline, there is still great uncertainty regarding the future fisheries agreements, and fisheries has turned as the most totemic issue in the EU-UK negotiations.

Fears are real that a no-deal Brexit could lead to serious incidents at sea, with violence breaking out between British and EU fishers, many of whom depend on access to UK fishing grounds for their economic survival. Particular hotspots are in the English Channel, in the Celtic Sea and in the disputed waters between Northern Ireland and the Irish Republic[21]. Newspaper headlines revealed that this explosive situation may be worsened by the likely insufficient capacity of the UK to patrol and control their fishing waters[22].

In the absence of a deal, the United Nations Convention on the Law of the Sea (UNCLOS) will ultimately apply, but key aspects of international fishing law are perceived in different and contradictory ways by different countries. In particular, the featured concept of "custom and practice" is advocated by EU fishing vessels to keep access to UK waters, thus not solving the basic dispute between EU and UK.

Globally, the Brexit is a serious threat to the sustainability and cooperation progresses achieved in the last fifteen years. Unilateral decision-making and resentment will only push for short-term protectionist decisions that may increase catches and fishing mortality, with potentially disastrous consequences for the status of shared fish stocks. Every political effort should be made to avoid returning to the situations of uncontrolled and unsustainably high fishing mortalities from the previous decades.

Interestingly, in the broader perspective, the Brexit reflects some profound political, historical and cultural elements that are deeply anchored in the relationships between national states and the EU in the topic of fisheries management. The UK fishers voted massively for Brexit, claiming regained control on "their fish" and "their waters" in spite of the obvious transboundary distribution of fish populations and of the long history of shared exploitation and share management.

Similar feelings and perceptions of ownership are however not specific to UK but are encountered everywhere and in every fishery. More than any other economic sectors, fisheries remain a national heritage in all EU countries. The cultural appeal to the population is much stronger than the actual contribution of that sector to the country's economy, not least because it provides employment and activity in remote coastal regions. Understanding these national and cultural perceptions is important, not only in the case of Brexit, which dominates the headlines now, but more generally in perceiving the differences in CFP's achievements and failures across the different Member States.

#### *5.1.1.2 The role of science*

There is a long story of cooperation between EU and UK scientists in the field of marine and fisheries science. UK scientists have been leading figures in ICES, not least in the strategic fields of stock assessment, data collection, management strategies evaluation, reference points, and sustainability science in the broader term. Therefore, a very first role for science is to maintain these historical links of high scientific standards, with the same requirements of quality level, openness and data sharing for providing advice on best

---

[21] https://www.independent.co.uk/news/uk/politics/brexit-no-deal-fishing-quotas-eu-boris-johnson-violence-scallop-wars-a9050431.html

[22] https://www.undercurrentnews.com/2019/08/12/leaked-memo-reveals-uk-concerns-over-ability-to-patrol-its-waters-post-brexit/

science. ICES is an independent scientific organisation, not an EU scientific body (unlike STECF), therefore Brexit should in theory not have major incidence on the involvement of UK in ICES. However, a major impediment remains, which is the termination of EU funding for the collection of fisheries data (DCF). It is hoped that UK will commit to maintaining high financing standards in data collection and marine research, in a collaborative manner with long-term objectives; but should this not happen, or should there be an interruption in UK data time series, ICES should also be prepared to react in the most appropriate way to maintain the quality of scientific advice. A direct corollary of this is that marine scientists must unanimously warn against the weakening of ICES advice and against the potentially disastrous unilateral TAC settings driven by short-term views referred above.

Secondly, even if and when an agreement is reached, one can expect that marine science will keep being solicited for informing ongoing political issues between EU and UK. An interesting biological question with direct implications for the so-called "zonal attachment of catches" argued to redistribute historical fishing quotas is to fully inform on the connectivity of populations. UK managers and fishers conveniently ignore that many adult fish found in UK waters are actually born and grown in shallow EU waters, and only migrate in the UK waters when old enough to feed and spawn! Indeed, most species undergo important migrations during their life cycle, both seasonally between spawning and fishing grounds, but also throughout the cycle. Eggs and larvae are transported by oceanic currents to nurseries in coastal waters, sometimes far from UK. Scientific Information on this connectivity is collected from survey data and from drifting and migration models, Taking North Sea herring as an example, one can see that smallest fish (aged 0) are found along the dutch and Danish coast, where they stay the first winter. At first summer, 1-year juveniles, they still mainly stay there but start being observed in UK waters. It is only as adults, aged 2 and over, that they are found primarily in UK waters, especially around Scotland in during summer where they are fished. Similar observations are made for many other species, to various extent.

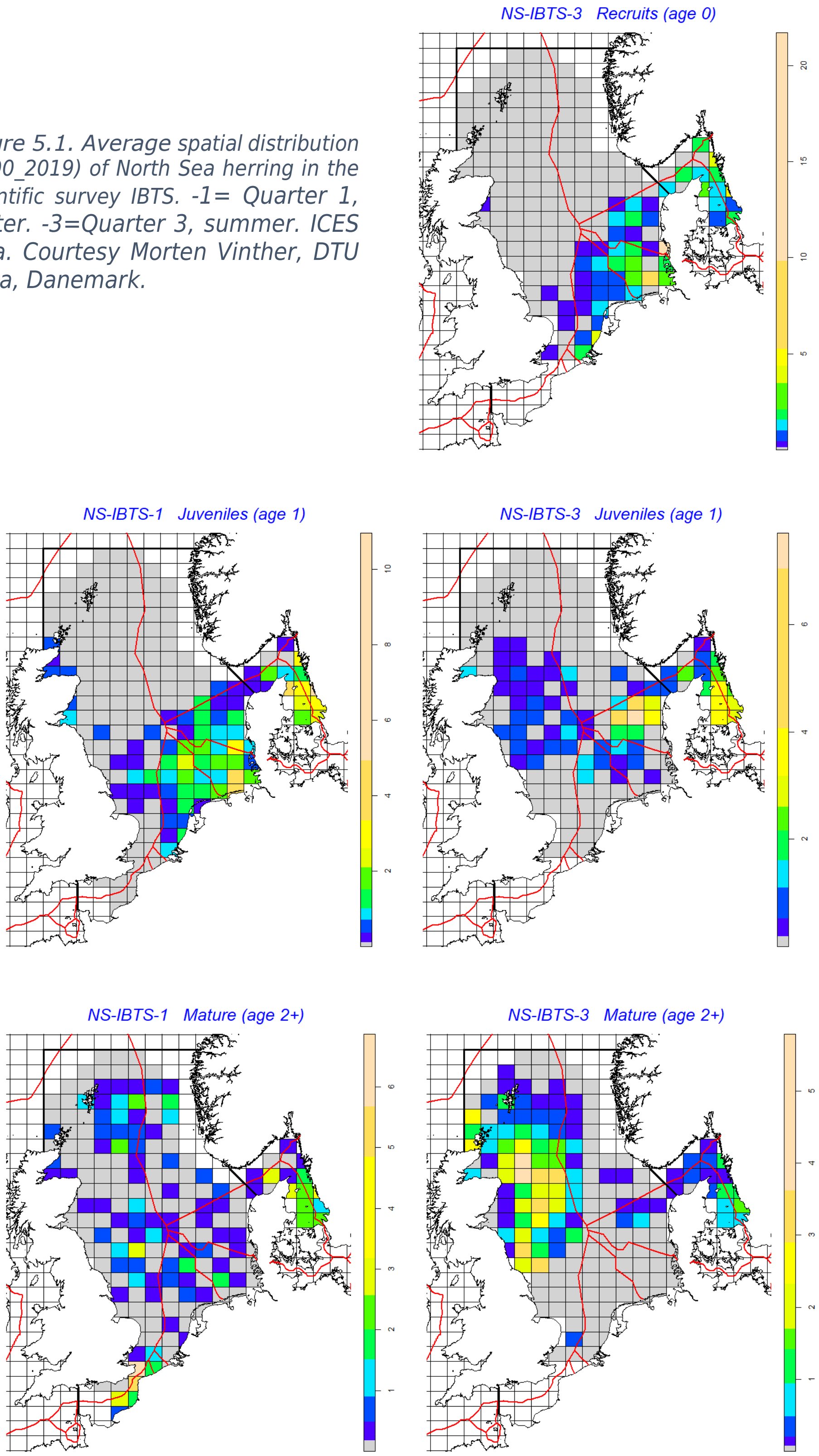



*Figure 5.1. Average spatial distribution (2000_2019) of North Sea herring in the scientific survey IBTS. -1= Quarter 1, winter. -3=Quarter 3, summer. ICES data. Courtesy Morten Vinther, DTU Aqua, Danemark.*

### 5.1.2 Landing obligation (LO)

#### *5.1.2.1 The challenge*

Many exemptions to the LO are foreseen in Article 15 of the 2013 CFP (high survival, de minimis due to selectivity difficult to achieve or disproportionate costs). Other regulatory adaptations have also been witnessed (minimum size reductions, TACs removals, TAC "top-up" increases, changes in prohibited species listing). Most of the political work in the first five years of LO implementation thus focused on agreeing on these exemptions in the regional discards plans, rather than on actually reducing discards (Rihan et al., 2019). This, associated with a delay in control and a poor level of enforcement, provided sufficient flexibility for the fishing industry to deal with the LO until now, in the sense that no fishery has yet been forced to an early closure because of choke species.

However, as noted above, progress towards achieving the ecological objectives of the LO of reducing discards and changing fishing practices are still imperceptible, after now almost two years of full implementation. Furthermore, the lack of support from the fishing industry remains strong. Many modalities from the LO are fiercely opposed by the fishing industry, the obligation to bring to land appearing more disputed than the objective of reducing discards *per se*. The feeling remains that the short-term economic impact on fishing activity are too high compared to the uncertain medium- to long-term environmental benefit.

The LO remains a complicated and rigid policy, intrinsically difficult to implement. To be fully complied with, it requires a real mind-set change in how fishers conduct their business, which can be slow to occur: Where they until now only aimed to maximise the catch value of what can be sold, they shall now also aim to minimise the catch quantity of what can't be sold.

Unless control becomes much more coercive with the compulsory use of electronic monitoring, it is thus difficult to anticipate substantial discards reduction to take place in the near future. The low-hanging fruits have been picked up, but the major political and technical barriers have not been overcome. In addition, the 2020 crises of Brexit and COVID clearly divert the political priority away from discards.

#### *5.1.2.2 The role of science*

The last five years have seen a frantic scientific activity around the topic of discards. In addition to the work presented in this thesis, several other investigation papers have been published recently on related topics. Also, numerous pilot studies have been undertaken to underpin the scientific evidence needed to secure the exemptions for a number of fleet segments and species (Rihan et al., 2019).

Certainly, much knowledge has been gained on causes and consequences of discarding, (Uhlmann et al., 2019). Not mentioned and presented here, important studies were conducted to better understand the ecological role of discards, and their contribution to the diet of other species including seabirds and scavengers (Depestele et al., 2019). One start also thinking about the role of discards as carbon sink, allowing carbon to stay in the water instead of being removed away (Mariani et al., 2020).

Thus, while the early inception of the landing obligation took place without much prior scientific consultation but as the results of important policy trade-offs in the late 2000s-early 2010s (see section 1.3.3 above), one dares say that science has played a very important role along the implementation period since 2015. It has delivered an impressive body of knowledge on all technical, ecological and socio-political aspects of discarding, putting data on facts and words on perceptions and opinions, and assisting at every stage of the dialogues between managers and stakeholders.

Yet, as we have seen, the political and technical barriers have largely not been overcome. Today, the situation appears a little bit paused with far fewer pilot studies and experiments being launched in the most recent years. As written above, it seems more than likely that the situation will not evolve much in the near future, thus proving that the policy has not fully succeeded in better aligning fishers' incentives with societal conservation goals.

The next future round of CFP negotiations in a couple of years will certainly need to reconsider every aspect of the landing obligation. The topic of discards will certainly not disappear from the political agenda and the blinded situation prevailing before will not return. But it will be necessary to re-discuss, in the light of the new scientific knowledge gained, what are the key objectives to be pursued (is this ecological sustainability or ethical reduction of resource waste? Reducing discards at sea or bringing to land?). This discussion is furthermore important considering that since 2013, new political frames have been launched under the umbrella of the EU Green Deal. Secondly, all the modalities of Article 15 shall be carefully assessed, considering what has worked where and what has not, and why.

Thus, holistic science could, and should, contribute to designing a more effective and inclusive future discards policy, providing global knowledge on the ecological and human stakes of sustainability, and pursuing the paradigm shift towards results-based management.

### 5.1.3 Multi-Annual Plans

#### *5.1.3.1 The challenge*

As of today, regional MAPs are already in place[23] in the Baltic Sea (since 2016), North Sea (2018), Western Waters (2019) and Western Mediterranean Sea (2019). Another MAP is in development for the demersal stocks of the Adriatic Sea, but not for the small pelagics, the largest fishery in the Mediterranean Sea, because of unresolved management conflicts and diverging opinions on the state of the stocks.

This recent history means that it is still too early to evaluate the functioning of these MAPs, and to draw lessons on their usefulness. An evaluation performed after three years of implementation means that there is only two years of data to reflect upon, which is insufficient to detect changes and to disentangle true trends from the natural inter-annual variability of the fish populations. For example, the evaluation of the 2008 EU cod plan (EC, 2008b) performed in 2011 highlighted at that time a number of implementation gaps and considered the plan as being largely ineffective (Kraak et al., 2013); whereas it is retrospectively obvious that fishing mortality on North Sea cod had reduced significantly after 2011, after some years of functioning of that plan. A rule of thumb would be that a minimum of five years would be necessary to detect and understand the changes induced by a management plan.

In the case of the first two MAPs already in place, this uncertainty on the actual effects of the plan may be further increased by the fact that that their implementation has coincided with dramatic worsening in the status of the key cod stocks both in the Baltic Sea and in the North Sea, which may confound their effects. While in the Baltic the changes are largely not imputable to the plan itself but to dramatic environmental changes, the situation is less clear in the North Sea, since other policy changes occurred concurrently, not least the removal of the restrictions on fishing effort previously in place.

[23] https://ec.europa.eu/fisheries/cfp/fishing_rules/multi_annual_plans_en

#### 5.1.3.2 The role of science

Designing integrated management considering the various species together in their mixed and multispecific fisheries context is an ambitious, innovative and challenging exercise, without easy and simple solutions and requiring trade-offs to be made. As we described in chapter 2 and 3, science was instrumental into making this to work, designing operational mixed fisheries frameworks and flexible reference points.

As time develops and more MAPs are applied, experience will tell whether these MAPs were able to provide their expected benefits of being a flexible legal frame, ensuring long-term conservation objectives against short-term decision making, while coping with the annual variability and uncertainty in the abundance of fish populations, and enhancing regional cooperation. Science will be a key player in building that evidence, and comparing outcomes and objectives.

In this context, one shall mention the current evolution of the mixed fisheries science, moving from average fleet-based annual patterns to a much closer understanding of individual differences between vessels and trips at a fine spatio-temporal scale (Dolder et al., 2020; ICES, 2020a). Fully integrated and spatially explicit individual-based models for mixed fisheries are also available to simulate a great variety of management strategies (Bastardie et al., 2014; Russo et al., 2019). These new approaches, although more data- and computer intensive, provide a very interesting platform for better understanding mixed fisheries processes by and simulating fishers' behaviour and incentives at their local scale. This mechanistic approach makes these models more robust and powerful to evaluate management scenarios and strategies outside of the range of historical observations (although these will always bear more uncertainty) and not relying on constant patterns' assumptions.

### 5.1.4 Monitoring, Control & Surveillance (MCS)

#### 5.1.4.1 The challenge

The CFP requirements for MCS were last revised in 2009 and a control regulation (Council Regulation (EC) 1224/2009) came into force on 1 January 2010. The objective was to increase compliance with fisheries rules, by creating a comprehensive and integrated system, based on harmonized control and inspection procedures, simpler rules to foster compliance and full traceability throughout the supply chain. This regulation was established prior to the 2013 CFP reform that introduced the ban on discarding (the LO), and reflects thus the control strategies, methodologies and challenges from more than 10 years ago.

The EC initiated therefore a new revision of the Control Regulation in May 2018. The revision intends to modernise, strengthen and simplify further the EU fisheries control system; to enhance traceability; to reinforce rules on lost fishing gears, and to introduce a revised mandate of the European Fisheries Control Agency (EFCA) in order to fully align its objectives with the CFP[24]. The EC is proposing a number of changes, including the possibility for Electronic Monitoring as a component of MCS for tracking compliance with the LO.

This revision should reduce the gap between a fisheries policy that is EU-centralised in one hand, and its monitoring, control and enforcement that is under the responsibility of the Member States' national agencies on the other hand. In this context, increasing the role of EFCA in ensuring cooperation and maintenance of common standards across Member States would add a fundamental step in the harmonisation of national fisheries control, hopefully resulting in increased compliance across the EU. Without effective MCS, the positive impacts of the ambitious objectives of the 2013 CFP (MSY objectives, MAPs, LO

[24] http://www.europarl.europa.eu/legislative-train/theme-fisheries/file-revision-of-the-fisheries-control-system

and regionalisation) on improving decision making and fisheries sustainability will be undermined.

At the time of writing this HDR (October 2020), the new control regulation was though still not in place, and uncertainties still remain on its future level of enforcement.

#### 5.1.4.2 *The role of science*

As explained above, effective fisheries management depends on the level of Monitoring, Control and Surveillance (MCS) and its effectiveness in making sure that management measures are being followed. Monitoring technologies are increasingly becoming a fundamental part of MCS. A whole system of new technologies that complement and communicate with each other are emerging, that can increase trust and transparency in fisheries and can be a game changer in the fight against IUU fishing.

New technological advances include among others the increased computing power of handheld devices; the proliferation of user-friendly Global Positioning System (GPS) and Global Navigation Satellites Systems (GNSS) applications; increased capacity for "big data" storage, sharing, and analysis; variety and improved durability of drones and low maintenance radar stations; accessibility and accuracy of satellite imagery; continuous improvements in on-board digital cameras and recorders; expanded use of Automatic Identification Systems (AIS) and Vessel Monitoring Systems (VMS), and the internet at sea (OECD, 2017)[25]. As described in section 4.3, Electronic Monitoring (EM) with cameras is increasingly used worldwide to monitor unwanted catches at sea, and computer vision applications that use machine learning and artificial intelligence is a research area where tremendous technological advancement is currently occurring. Block chain technology could also have promising applications in fisheries, for example for the efficient trading of fishing rights / catch shares and the traceability of landings throughout the value chain (Probst, 2019). To follow development, ICES has recently launched a new working group on Technology Integration for Fishery-Dependent Data (WGTIFD) that aims at gathering best practices for implementing monitoring technologies around the world[26].

A challenge for European policymakers is now how to integrate these new technologies in the toolbox of management measures and policies already in place.

The recent launch of the CATCH software by the EC[27] is an example of how technology can progress the fight against IUU, by providing a cross-validation tool to paper records (catch certificates), although it still requires Council and EP approval to be mandatory. Another example is the introduction of reporting obligations for the small-scale sector proposed in the revised Control regulation described above, which is based in part on the new possibilities to use technologies that were not available in the last CFP reform, associated to a pressing need to assess and manage the comprehensive impact of small-scale (and recreational) fisheries.

The wider use of these technologies is however still limited by their cost, by their complex data requirements, by the challenges in sharing such data among fisheries management authorities and by the limited numbers of individuals trained to use these tools (OECD, 2017), although continuous technological progress contribute to ever-reducing costs and improved user-friendliness. More importantly though, their use is significantly limited by their lack of acceptance by the fishing industry. At present, the most controversial use of these new monitoring technologies is certainly the implementation of electronic monitoring

---

[25] https://www.oecd.org/greengrowth/GGSD_2017_Issue%20Paper_New%20technologies%20in%20Fisheries_WEB.pdf

[26] https://www.ices.dk/community/groups/Pages/WGTIFD.aspx

[27] https://www.seafoodsource.com/news/supply-trade/eu-launches-catch-software-to-reduce-chance-of-iuu-products-entering-market

onboard fishing vessels, among others for the control of the LO. As described above, a few successful trials were conducted in Europe prior to the implementation of the LO, combining voluntary use of cameras to monitor all catches (both the landed ones and the ones discarded at sea) against appropriate incentives in the form of increased quotas or less stringent technical rules (James *et al.*, 2019; v. Helmond *et al.*, 2020).

Clearly, the LO has been a significant game changer, and its implication for the global uptake of EM, from voluntary pilots to compulsory use is still to be seen. Noticeably, many of the possible incentives used in voluntary trials such as quota increases, exemptions, reduced control, have already been given to the fishing industry in the discard plans, without additional monitoring requirements (neither compulsory nor voluntary). It is thus not surprising that the acceptance of this MCS approach is still lacking in large parts of the European fishing industry, and changes in mind-sets are slow. Nevertheless, science has here again a key role to play. Showing the good and helpful use of accurate fisheries data for science and advice, and contributing to design positive incentives in the use of EM can help soften the reluctance of the fishing industry and mitigate the "Big Brother" feeling hampering uptake.

### 5.1.5 .Regionalisation

#### *5.1.5.1 The challenge*

Increased regionalisation and enhanced regional cooperation for a number of instruments and measures was a fundamental innovation of the 2013 CFP, as a response to a common perception that the CFP was too centralised. It is now possible for Member States having a direct management interest in a fishery to cooperate with one another in formulating joint recommendations. The Commission may then adopt those measures by means of delegated or implementing acts.

Numerous joint recommendations have indeed already been formulated, primarily, but not only, for the establishment of the discard plans and management plans explained above. In the Mediterranean Sea in particular, this form for regional cooperation is creating a new dynamic, previous management plans having been always defined at the scale of a single Member State or even smaller sub-national scale.

As time develops and experience with regionalisation builds up, a number of challenges started however emerge. (van Hoof et al., 2019) claimed that regionalisation creates another layer of governance in between Member States and EU institutions, with an unclear functioning. Joint Recommendations are emitted by High-Level Groups (HLG) of Member States, but the processes and discussions underlying decision-making, including the extent of the involvement of stakeholders and scientists, are not transparent. A striking illustration of this is that most, if not all, regional groups (e.g. BALTFISH for the Baltic, Scheveningen Group for the North Sea etc.) do not even have a dedicated public website keeping open records of meetings and decisions.

Another challenge is about finding the difficult balance between maintaining some fundamental principles and objectives of the CFP applicable to all European fisheries in the one hand, and leaving some room for regional divergence in the other hand. In essence, the regional groups can diverge on some modalities for the application of CFP elements, but not on the elements themselves. Some of these elements like the LO are described in very prescriptive and detailed ways in the CFP, leaving the regional groups with only a limited range of options to choose in between but no arena to fully discuss the actual need and usefulness of the elements (van Hoof et al., 2019).

#### 5.1.5.2 The role of science

The use of social and human sciences (SHS) to describe the evolution of regionalisation is very interesting in this context, bringing new insights on a move which, at first sight, makes rather intuitive sense. SHS analyse how this additional layer of governance is changing the current relations of power between the existing layers (EU, Member States, stakeholders), and whether decentralisation is achieving any positive outcomes.

Also, learning on whether similar positive sustainability outcomes might be reached using different regional paths would be instrumental into designing the future CFP, bringing evidence and trust that flexible management involving results-based approaches can create more positive incentives.

### A new era for the Mediterranean and Black Seas

#### 5.1.5.3 The challenge

The Mediterranean and Black Seas have long been left aside by the CFP, governed by their own regulations, with unclear roles and responsibilities of multiple layers of decision: National states, EU and the General Fisheries Commission for the Mediterranean (GFCM) under the Food and Agriculture Organisation of the United Nations (FAO). The management of the fisheries in that region has thus been both complex and largely ineffective, and there are no TACs in place except for Bluefin tuna and swordfish. As a result, there is a general agreement that the vast majority of the stocks in the Mediterranean and Black Seas are strongly overexploited (STECF, 2020). In addition, the Mediterranean Sea holds a number of sad records, being Europe's most polluted[28] and most trawled sea.

In the most recent years though, the area has gained a renewed focus. A number of initiatives have emerged within a global process commonly referred to as « MedFish4Ever »[29] that is transforming the governance in the region. Through a Ministerial Declaration signed in Malta in March 2017, 16 Mediterranean countries and the EU committed to improve the situation of Mediterranean fisheries over the next decade through a series of ambitious targets and activities towards strengthening fisheries management and governance, some of which are described in the GFCM Mid-term strategy (2017-2020) towards the sustainability of Mediterranean and Black Sea fisheries[30]. This was followed by a similar declaration for the Black Sea signed in Sofia in June 2018.

A follow-up conference was organised in June 2019 to review progress made in relation to the declared targets and highlight gaps where continued and additional efforts were needed. Some achievements were highlighted by the EU at this conference[31], but tremendous efforts are still required to achieve the targets. The signing countries renewed their commitments towards this declaration, and defined key priorities, primarily the fight against Illegal, Unreported and Unregulated (IUU) fishing and the social development for small-scale fisheries, promoting decent work and reducing vulnerabilities for fishers in the region's coastal communities. Appropriate management measures are still to be agreed for the small pelagic fisheries in the Mediterranean Sea.

A major challenge in the coming years will be whether the current initiatives will be sufficient and successful at reducing fishing mortality and recovering the fish stocks, or whether new measures are needed. For example, the MAP agreed in 2019 for the demersal

---

[28] https://wwz.ifremer.fr/Espace-Presse/Communiques-de-presse/Dechets-marins-en-Mediterranee-une-hausse-moderee-et-une-mission-en-cours

[29] http://www.fao.org/gfcm/meetings/medfish4ever/en/

[30] http://www.fao.org/3/a-i7340e.pdf

[31] https://ec.europa.eu/fisheries/press/gfcm-high-level-conference-medfish4ever-initiatives-advances-and-renewed-commitments-11-12_bg

fisheries in the Western Mediterranean (Regulation (EU) 2019/1022) foresees a reduction of fishing effort in the order of 40% in the next five years. The dedicated STECF expert working group (STECF, 2018b) [that I chaired] warned that this will likely not translate in equivalent reductions in fishing mortality due to the inherent shortcomings in managing fisheries with effort limitations rather than with TACs. The main issue is the known incentives for fishing vessels to become more powerful and efficient when fishing effort is constrained, in order to maintain unchanged levels of catches and revenue within a shorter period of fishing time.

#### *5.1.5.4 The role of science*

The role and power of science in the Mediterranean and Black Seas is evolving rapidly in these recent years, at the same pace as the political focus increases. In a way, the region is ongoing the same transformation as what happened in the Atlantic one or two decades ago. Regional cooperation increases, largely as the result of increased financing by the EU. Data collection and stock assessment is increasingly coordinated and mutualised.

Progresses can be slow though. Some issues and conflicts still remain, both in agreeing on the cause and extent of issues and on the ways forward[32] (Carpi et al., 2017). More years and longer time series of data are probably needed before settling old disputes.

In addition, the number of assessed stocks remain low compared to the number of stocks of commercial importance. In the Western Mediterranean demersal fisheries, the species assessed and currently included in the multiannual management plan typically makes only up to 20-40% of the landings of the fleets. Sustained investments in science are thus absolutely needed to increase the number of stocks regularly monitored and assessed. This issue is however particularly challenging, since many of the important commercial species that are currently not assessed are very coastal (and thus out of reach of the established scientific surveys) and/or notoriously difficult to assess because of their biological specificities (such as the cephalopods and the molluscs), so the current limitations are not only of financial origin.

## 5.2 Biological and ecological challenges

### 5.2.1 Ecosystem-based fisheries management

#### *5.2.1.1 The challenge*

Ecosystem-based fisheries management (EBFM) is a holistic way of managing fisheries and marine resources by taking into account the entire ecosystem of the species being managed. The goal of EBFM is to maintain ecosystems in a healthy, productive, and resilient condition so they can provide the services humans want and need[33].

This broad definition covers many different aspects, and a huge amount of science has been dedicated in the last decades to advance understanding of the marine ecosystems, and to integrate this into useful advice to meet current and emerging conservation, management, and sustainability goals[34]. For example, ICES publishes now up-to-date Ecosystem Overviews[35] for the various European regions, describing linkages between human activities, pressures, and states.

A lot of progresses have thus already been achieved, and it can be said that many of the new policy objectives under the current CFP (MSY, LO and regional MAPs) are attempts to include broader ecosystem considerations into the traditional frame of single-stock

32 https://www.europarl.europa.eu/committees/en/product/product-details/20201022CHE07661
33 https://www.fisheries.noaa.gov/insight/understanding-ecosystem-based-fisheries-management
34 http://www.ices.dk/explore-us/strategicplan/Pages/default.aspx
35 http://www.ices.dk/community/advisory-process/Pages/Ecosystem-overviews.aspx

fisheries management. However, much more remains to be done. In particular, a major need would be a better alignment of the CFP, of the Marine Strategy Framework Directive (MSFD) and of the EU Birds and Habitats directives under an integrated policy.

#### *5.2.1.2 The role of science*

There is no doubt that EBFM underpins basically every step of marine and fisheries science nowadays. The concept is referred to extensively in every strategic document for research agenda (cf e.g. UN Ocean Decade), and there is not much new insights I could bring here.

Nevertheless, behind the obvious soundness of the concept is a difficult task. EBFM is a typical example of a wicked problem without easy solution, where different stakeholders will value different options. Typically, one can agree on the general goal but not necessarily on the path to get there, valuing an approach either "nature-first" or "people first".

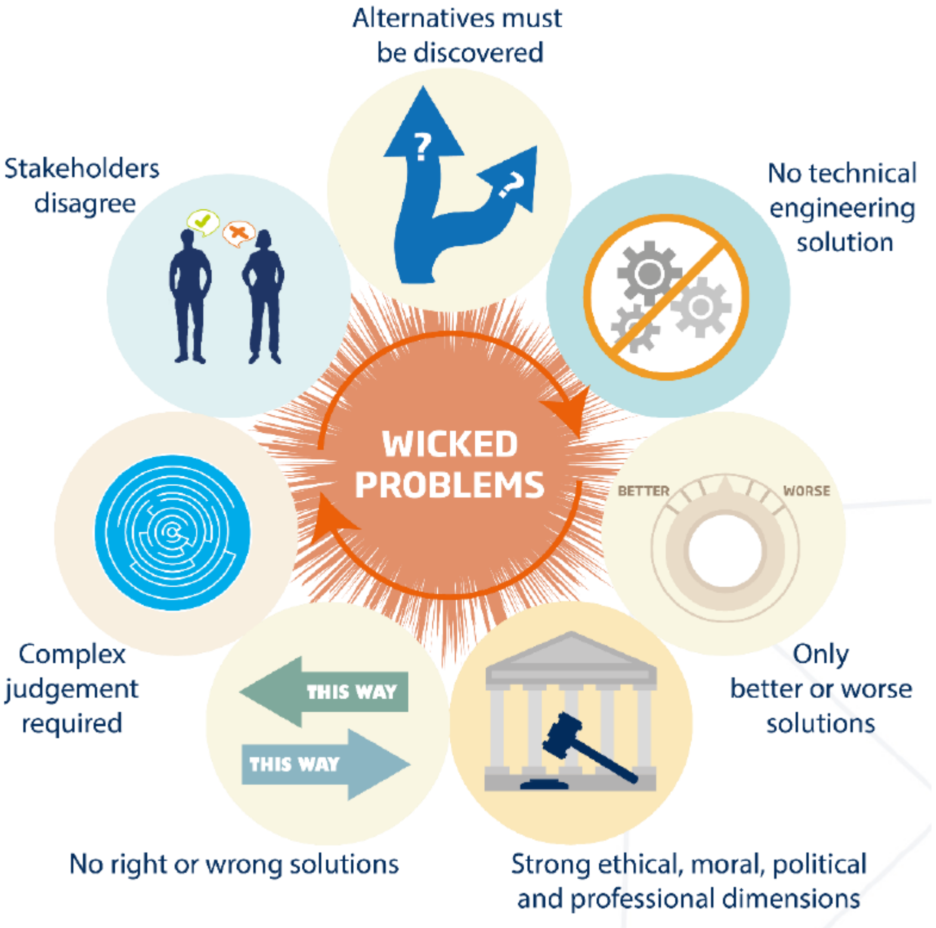



*Figure 5.2 The wicked EBFM problem. copied from an ICES presentation by M. Dickey-Collas*

The experience with MSFD shows the difficulty to identify and monitor proper indicators of pressure and state. Consensus on ecosystem indicators require data, time series, good science and a clear policy frame.

In this context, ICES leads a pragmatic approach, aiming to achieve a quantitative assessment framework for each component of the fisheries ecosystem. For example, major progresses have been achieved in the recent years in quantifying seafloor impact, combining spatial information on fisheries pressure and the modelling of seafloor integrity and sensitivity. Similar progresses are ongoing regarding e.g. bycatch of sensitive species, competition for space, and even human impact, through the mapping of social equity and community resilience. Another pragmatic integrated EBFM framework has also been suggested by (Link et al., 2020). Thinking back into how the MSY concept was adapted from a point estimate to a consensus acceptable area, EBFM could be thought along the line of the "Multi-objective Pretty Good Yield" advocated by (Rindorf, Dichmont, et al., 2017) and described in section 3.6.

Ultimately, one may keep also in mind that an H2020 call dealing with "Fisheries in a full ecosystem context" has been launched in 2020. At the time of writing this HDR, proposals are still under evaluation, but there is no doubt that the outcomes of this call will progress towards making EBFM further operational in the European context.

### 5.2.2 Climate and environmental changes

#### *5.2.2.1 The challenge*

This point is so important that I will close this thesis on this subject. It is increasingly evident that climate change is already having significant impacts on marine ecosystems and on the dependent communities (Free et al., 2019). Recent scientific advances are improving our ability to understand, project, and assess the consequences of different levels of climate change during the 21st century (Pörtner et al., 2019), and there hardly goes a week without new scientific studies being published on the subject, with dire predictions. Cartoons examples of this are popularly illustrated in (Link et al., 2018). Direct challenges on fisheries include shifts in species distributions, invasive species and productivity losses (in the average range of 5% per degree of global warming, (Lotze et al., 2019), although with important regional variations. In the medium-term climate change will thus profoundly affect human and animal health and food security worldwide. This happens both through the progressive shifts in the states of nature following water warming and acidification, and reduced oxygenation, and through high-impact adverse extreme events such as heat waves, which are considered by some scientists to be the largest threat to ocean life (Pinsky et al., 2019).

Undoubtedly, changes in productivity will affect differently the various European and world regions, with more winners in the north and losers in the south, since for the high latitude regions, catch potential is projected to increase, or show less of a decrease than in the tropics (Barange et al., 2018; Hastings et al., 2020).

A key message to managers though is that these estimated catch reductions only compare to the *maximum* catch potential, and not to the *current* levels of catches. What this means is that effective and adaptive management at MSY objective accounting both for changes in fish distribution (denoted "Range Shift" in the figure below) and reduced productivity could offset some of the climate-related loss and maintain productive and profitable fisheries even under a range of warming scenarios (Duarte et al., 2020; Gaines et al., 2018).

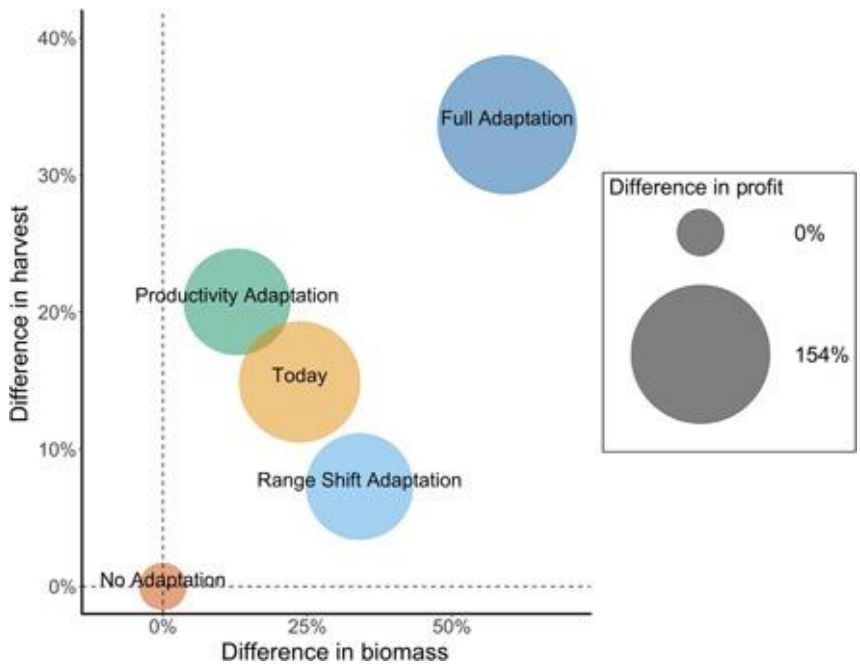



*Figure 5.3: Differences in harvest, profit, and biomass in the world fisheries, relative to "No Adaptation" for Representative Concentration Pathways RCP 6.0 in 2100 (corresponding to a global mean temperature expected to increase by 2.2°C by 2100) Source: Gaines* et al. *(2018)*

Translating this into appropriate management actions and policies remain however an ongoing challenge. Current management tools are often not well suited for managing the same systems under climate change, and there are many significant institutional, legal, financial and logistical barriers to successful adaptation. Ultimately, the impacts of climate change on the fisheries and aquaculture sector will thus be determined by the sector's ability to adapt, and the FAO published guidance documents on the tools and methods available to facilitate and strengthen such adaptation (Barange *et al.*, 2018).

For European fisheries, one of important policy challenges induced by climate change lies in the fixed "relative stability" allocation keys between Member States. These distribution keys for each TAC were agreed during the 70s-80s and not updated since. As noted above, the issue on "choke species" highlighted by the Landing Obligation demonstrates already that these keys do not align anymore with today's distribution of fish, with some Member States having no or too little historical quota for species that are now abundant in their waters. For example, (ICES, 2017) identified eight "great movers" species whose distributional shifts are already affecting TAC management areas such as anchovy (*Engraulis encrasicolus*), cod (*Gadus morhua*), hake (*Merluccius merluccius*), herring (*Clupea harengus*), mackerel (*Scomber scombrus*), horse mackerel (*Trachurus trachurus*), sole (*Solea solea*) and plaice (*Pleuronectes platessa*). Another emblematic example is the recent return of Bluefin tuna (*Thunnus thynnus*) in northern Europe.

Existing mechanisms of quotas swaps and trade are already insufficient to compensate for this unbalance today, so this issue will undoubtedly only worsen under climate change scenarios. This will lead to increased conflicts and suboptimal utilization of fishing opportunities at EU level. There is thus an urging need for policy makers to define new ways to better share and fully use fishing opportunities, combining fixed and adaptive features at different scales of time and space that would improve management effectiveness and efficiency (Holsman *et al.*, 2019).

#### *5.2.2.2 The role of science*

Here again, as for EBFM, the role of science is hardly to be discussed given how important the question is, and how much knowledge will be required, both to characterize impacts (on marine life and on human livelihood) to assess adaptation scenarios. All fields of marine science will be somehow confronted to the impact of global change on the dynamic of life in the ocean, from the deep sea microbial communities to the large whales, from global scale to local impact. No doubt that this transversal question must perfuse in every domain of research and advice, as it already increasingly does.

# 6 Conclusions

The 2002 reform of the CFP initiated a number of significant improvements, in the form of long-term management plans and stakeholders' involvement. The 2013 reform aimed to build further on these changes in the form of MSY objective, multi-annual plans and regionalisation. But most importantly, the reform aimed to be the basis for a profound change in the way fisheries management is conducted in Europe. The landing obligation is turning the basic underlying principles upside down by aiming to make the fishing industry accountable for its impact on all species and sizes caught, and not only on the share that can be landed and sold. This was a major step towards ecosystem-based fisheries management.

Implementing such a paradigm shift does not, however, occur overnight, and many issues are still unresolved. There are numerous historical, structural and institutional barriers that are difficult to overcome. In the light of my own scientific and advisory endeavour during 20 years of research in fisheries science, I reviewed in this HDR manuscript a number of these issues and challenges, focusing primarily on the slow achievement of the key CFP objectives i) the too slow progresses to achieve MSY in EU fisheries especially in mixed and multi-specific fisheries, and ii) the persistent issue of discards in EU fisheries, which the landing obligation has so far failed to improve.

In addition, new challenges like Brexit and climate change jeopardise the outcomes of policy decisions. These two issues relate to a large extent to the sharing of fishing opportunities among (but also within) Member States, as is also the case for the central issue of "choke species" for the landing obligation: These issues reveal the obsolescence of the current relative stability allocation keys, agreed during the 70s-80s but never updated since. This leads to conflicts and to the suboptimal exploitation of resources. There is a compelling need to define new and better ways of sharing fishing opportunities.

The current reform of the CFP has already entered its second half. Given the current rates of progress, several objectives may thus not be attained as stated in the CFP, and the relative balance between successes and failures will undoubtedly shape the discussions surrounding the next reform of the CFP. In this regards, the holistic scientific view focusing on the complex ecological and human stakes of fisheries sustainability could bring important insights into future policy developments.

# 7 References


Aranda, M., Ulrich, C., LeGallic, B., Borges, L., Metz, S., Prellezo, R., & Santurtún, M. (2019). *Researchfor PECH Committee—EU fisheriespolicy–latest developments and future challenges*. https://www.europarl.europa.eu/RegData/etudes/STUD/2019/629202/IPOL_STU(2019)629202_EN.pdf

Barange, M., Bahri, T., Beveridge, M., Cochrane, K., Funge-Smith, S., & Poulain, F. (2018). *Impacts of climate change on fisheries and aquaculture – synthesis of current knowledge, adaptation and mitigation options*. http://www.fao.org/3/i9705en/i9705en.pdf

Bastardie, F., Nielsen, J. R., & Miethe, T. (2014). DISPLACE: A dynamic, individual-based model for spatial fishing planning and effort displacement - integrating underlying fish population models. *Canadian Journal of Fisheries and Aquatic Sciences*. https://doi.org/10.1139/cjfas-2013-0126

Batsleer, J., Hamon, K. G., Overzee, H. M. J. van, Rijnsdorp, A. D., & Poos, J. J. (2015). High-grading and over-quota discarding in mixed fisheries. *Rev Fish Biol Fisheries*, *25*, 15–736. https://doi.org/10.1007/s11160-015-9403-0

Beverton, R. J. H., & Holt, S. J. (1957). On the Dynamics of Exploited Fish Populations. *Fishery Investigations (Great Britain, Ministry of Agriculture, Fisheries, and Food)*, *19*.

Broadhurst, M. K., Suuronen, P., & Hulme, A. (2006). Estimating collateral mortality from towed fishing gear. In *Fish and Fisheries* (Vol. 7, Issue 3). https://doi.org/10.1111/j.1467-2979.2006.00213.x

Calderwood, J., Plet-Hansen, K. S., Ulrich, C., & Reid, D. G. (2020). Fishing for euros: how mapping applications can assist in maintaining revenues under the Landing Obligation. *ICES Journal of Marine Science*. https://doi.org/10.1093/icesjms/fsaa116

Carpenter, G., & Kleinjans, R. (2017). *Who gets to fish? The allocation of fishing opportunities in EU Member States*. https://neweconomics.org/2017/03/who-gets-to-fish

Carpenter, G., Kleinjans, R., Villasante, S., & O'Leary, B. C. (2016). Landing the blame: The influence of EU Member States on quota setting. *Marine Policy*, *64*, 9–15. https://doi.org/10.1016/j.marpol.2015.11.001

Carpi, P., Scarcella, G., & Cardinale, M. (2017). The Saga of the Management of Fisheries in the Adriatic Sea: History, Flaws, Difficulties, and Successes toward the Application of the Common Fisheries Policy in the Mediterranean. *Frontiers in Marine Science*. https://doi.org/10.3389/fmars.2017.00423

Catchpole, T. L., Feekings, J. P., Madsen, N., Palialexis, A., Vassilopoulou, V., Valeiras, J., Garcia, T., Nikolic, N., & Rochet, M.-J. (2014). Using inferred drivers of discarding behaviour to evaluate discard mitigation measures. *ICES Journal of Marine Science*, *71*(5), 1277–1285. https://doi.org/10.1093/icesjms/fst170

Davis, M. W. (2002). Key principles for understanding fish bycatch discard mortality. *Canadian Journal of Fisheries and Aquatic Sciences*, *59*(11), 1834–1843. https://doi.org/10.1139/f02-139

Degnbol, Paul. (2015). Linking targets and limits to practical fisheries management. *ICES/MYFISH Symposium on Targets and Limits for Long-Term Fisheries Management*. http://myfishproject.eu/images/MYFISH/symposium/Talks/PoulDegnbol.pdf

Degnbol, Poul, Gislason, H., Hanna, S., Jentoft, S., Raakjær Nielsen, J., Sverdrup-Jensen, S., & Clyde Wilson, D. (2006). Painting the floor with a hammer: Technical fixes in fisheries management. *Marine Policy*, *30*(5), 534–543. https://doi.org/10.1016/j.marpol.2005.07.002

Depestele, J., Feekings, J., Reid, D. G., Cook, R., Gascuel, D., Girardin, R., Heath, M., Hernvann, P.-Y., Morato, T., Soszynski, A., & Savina-Rolland, M. (2019). The Impact of Fisheries Discards on Scavengers in the Sea. In *The European Landing Obligation* (pp. 129–162). Springer International Publishing. https://doi.org/10.1007/978-3-030-03308-8_7

Deporte, N., Ulrich, C., Mahevas, S., Demaneche, S., & Bastardie, F. (2012). Regional metier definition: a comparative investigation of statistical methods using a workflow applied to international otter trawl fisheries in the North Sea. *ICES Journal of Marine Science*, *69*(2), 331–342. https://doi.org/10.1093/icesjms/fsr197

Diamond, B., & Beukers-Stewart, B. D. (2011). Fisheries Discards in the North Sea : Waste of Resources or a Necessary Evil? *Reviews in Fisheries Science*, *19 (3)*(July 2015), 231–245. https://doi.org/10.1080/10641262.2011.585432

Dolder, P. J., Minto, C., Guarini, J. M., & Poos, J. J. (2020). Highly resolved spatiotemporal simulations for exploring mixed fishery dynamics. *Ecological Modelling*. https://doi.org/10.1016/j.ecolmodel.2020.109000

Duarte, C. M., Agusti, S., Barbier, E., Britten, G. L., Castilla, J. C., Gattuso, J.-P., Fulweiler, R. W., Hughes, T. P., Knowlton, N., Lovelock, C. E., Lotze, H. K., Predragovic, M., Poloczanska, E., Roberts, C., & Worm, B. (2020). Rebuilding marine life. *Nature*, *580*(7801), 39–51. https://doi.org/10.1038/s41586-020-2146-7

EC. (2002). COUNCIL REGULATION (EC) No 2371/2002 of 20 December 2002 on the conservation and sustainable exploitation of fisheries resources under the CommonFisheries Policy. *Official Journal of the European Communities*, *L 358/59*.

EC. (2004). Council Regulation (EC) No 423/2004 of 26 February 2004 establishing measures for the recovery of cod stocks. *Official Journal of the European Union*, *L 70/8*.

EC. (2008a). Council Regulation (EC) No. 199/2008 of 25 February 2008 concerning the establishment of a Community framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the common fisheries policy. *Official Journal of the European Union*, *L60/1*.

EC. (2008b). Council Regulation (EC) No 1342/2008 of 18 December 2008 establishing a long-term plan for cod stocks and the fisheries exploiting those stocks and repealing Regulation (EC) No 423/2004. *Official Journal of the European Union*, *L 348/20*.

Eliasen, S. Q., Feekings, J., Krag, L., Veiga-Malta, T., Mortensen, L. O., & Ulrich, C. (2019). The landing obligation calls for a more flexible technical gear regulation in EU waters – Greater industry involvement could support development of gear modifications. *Marine Policy*, *99*, 173–180. https://doi.org/10.1016/j.marpol.2018.10.020

EU. (2014). *Task Force on multiannual plans. Final report April 2014*. http://www.europarl.europa.eu/meetdocs/2009_2014/documents/pech/dv/taskfor/taskforce.pdf

EU. (2018). Regulation (EU) 2018/973 of the European Parliament and of the Council of 4 July 2018 establishing a multiannual plan for demersal stocks in the North Sea and the fisheries exploiting those stocks, specifying details of the implementation of the landing o. *Official Journal of the European Union*, *L 179/1*. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32018R0973&from=en

European Parliament and Council of the European Union. (2013). REGULATION (EU) No 1380/2013 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2013 on the Common Fisheries Policy, amending Council Regulations (EC) No 1954/2003 and (EC) No 1224/2009 and repealing Council Regulations (EC) No 2371/2002 and (EC. *Official Journal of the European Union*, *L354*(28.12.2013), 22–61.

Feekings, J., O'Neill, F. G., Krag, L., Ulrich, C., & Veiga Malta, T. (2019). An evaluation of European initiatives established to encourage industry-led development of selective fishing gears. *Fisheries Management and Ecology*, *26*(6), 650–660. https://doi.org/10.1111/fme.12379

Fitzpatrick, M., & Nielsen, K. N. (2016). *DiscardLess Policy Brief No1: Year 1 of the Landing Obligation, key issues from the Baltic and Pelagic fisheries*. https://doi.org/10.5281/zenodo.215155

Frangoudes, K., & Guillen, J. (2015). *Appropriate economic and social criteria to evaluate the Discard Mitigation Strategies and the defined management scenarios*. https://doi.org/10.5281/zenodo.229373

Free, C. M., Thorson, J. T., Pinsky, M. L., Oken, K. L., Wiedenmann, J., & Jensen, O. P. (2019). Impacts of historical warming on marine fisheries production. *Science*, *363*(6430), 979–983. https://doi.org/10.1126/science.aau1758

Gaines, S. D., Costello, C., Owashi, B., Mangin, T., Bone, J., Molinos, J. G., Burden, M., Dennis, H., Halpern, B. S., Kappel, C. V., Kleisner, K. M., & Ovando, D. (2018). Improved fisheries management could offset many negative effects of climate change. *Science Advances*, *4*(8), eaao1378. https://doi.org/10.1126/sciadv.aao1378

Gallie, W. B. (1956). IX.—Essentially Contested Concepts. *Proceedings of the Aristotelian Society*. https://doi.org/10.1093/aristotelian/56.1.167

Guillen, J., Holmes, J. S., Carvalho, N., Casey, J., Dörner, H., Gibin, M., Mannini, A., Vasilakopoulos, P., & Zanzi, A. (2018). A Review of the European Union Landing Obligation Focusing on Its Implications for Fisheries and the Environment. *Sustainability*, *10*(4), 900. https://doi.org/10.3390/su10040900

Hastings, R. A., Rutterford, L. A., Freer, J. J., Collins, R. A., Simpson, S. D., & Genner, M. J. (2020). Climate Change Drives Poleward Increases and Equatorward Declines in Marine Species. *Current Biology*. https://doi.org/10.1016/j.cub.2020.02.043

Hilborn, R. (2010). Pretty Good Yield and exploited fishes. *Marine Policy*, *34*(1), 193–196. https://doi.org/10.1016/j.marpol.2009.04.013

Hjort, J. (1914). Fluctuations in the great fisheries of northern Europe viewed in the light of biological research. *Rapports et ProcésVerbaux Des Réunions Du Conseil Permanent International Pour l'Exploration de La Mer*, *20*(1), 228. https://doi.org/c:\Pubs\Classics

Hoff, A., Frost, H., Andersen, P., Prellezo, R., Rueda, L., Triantaphyllidis, G., Argyrou, I., Tsikliras, A., Motova, A., Lehuta, S., Curtis, H., Rodríguez-Rodríguez, G., Ballesteros, H. M., Valeiras, J., & Bellido, J. M. (2019). Potential Economic Consequences of the Landing Obligation. In *The European Landing Obligation* (pp. 109–128). Springer International Publishing. https://doi.org/10.1007/978-3-030-03308-8_6

ICES. (2013). Multispecies considerations for the North Sea stocks. In *ICES Advice 2013, Book 6* (p. 9). http://www.ices.dk/sites/pub/Publication Reports/Advice/2013/2013/mult-NS.pdf

ICES. (2015a). EU request to ICES to provide FMSY ranges for selected North Sea and Baltic Sea stocks. In *ICES Advice 2015, Book 6* (p. 11 pp). http://www.ices.dk/sites/pub/Publication Reports/Advice/2015/Special_Requests/EU_FMSY_ranges_for_selected_NS_and_BS_stocks.p df

ICES. (2015b). *Report of the Joint ICES-MYFISH Workshop to consider the basis for FMSY ranges for all stocks (WKMSYREF3), 17–21 November 2014, Charlottenlund, Denmark.* https://doi.org/ICES CM 2014/ACOM:64

ICES. (2017). *EU request on distributional shifts in fish stocks*. http://www.ices.dk/sites/pub/Publication Reports/Advice/2017/Special_requests/eu.2017.05.pdf

ICES. (2019). *Greater North Sea Ecoregion – Fisheries overview, including mixed-fisheries considerations*. https://www.ices.dk/sites/pub/Publication Reports/Advice/2019/2019/FisheriesOverview_GreaterNorthSea_2019.pdf

ICES. (2020a). *ICES/Probyfish Workshop on identification of target and bycatch species(WKTARGET)*. https://doi.org/10.17895/ices.pub.5980

ICES. (2020b). *Working Group on Mixed Fisheries Advice (WGMIXFISH-ADVICE; outputs from 2019 meeting)*. https://doi.org/http://doi.org/10.17895/ices.pub.7508

James, K. M., Campbell, N., Viðarsson, J. R., Vilas, C., Plet-Hansen, K. S., Borges, L., González, Ó., van Helmond, A. T. M. M., Pérez-Martín, R. I., Antelo, L. T., Pérez-Bouzada, J., Ulrich, C., Vidarsson, J. R., Vilas, C., Plet-Hansen, K. S., Borges, L., González, Ó., van Helmond, A. T. M. M., Pérez-Martín, R. I., … Ulrich, C. (2019). Tools and Technologies for the Monitoring, Control and Surveillance of Unwanted Catches. In *The European Landing Obligation: Reducing Discards in Complex, Multi-Species and Multi-Jurisdictional Fisheries* (pp. 363–382). Springer International Publishing. https://doi.org/10.1007/978-3-030-03308-8_18

Karp, W. A., Breen, M., Borges, L., Fitzpatrick, M., Kennelly, S. J., Kolding, J., Nielsen, K. N., Viðarsson, J. R., Cocas, L., & Leadbitter, D. (2019). Strategies Used Throughout the World to Manage Fisheries Discards – Lessons for Implementation of the EU Landing Obligation. In *The European Landing Obligation* (pp. 3–26). Springer International Publishing. https://doi.org/10.1007/978-3-030-03308-8_1

Kelleher, K. (2005). Discards in the world ' s marine fisheries An update. *Fish. Tech. Pap 470. FAO.*, 131. https://doi.org/10.1136/ebmed-2011-0012

Kempf, A., Mumford, J., Levontin, P., Leach, A., Hoff, A., Hamon, K. G., Bartelings, H., Vinther, M., Stäbler, M., Poos, J. J., Smout, S., Frost, H., van den Burg, S., Ulrich, C., & Rindorf, A. (2016). The MSY concept in a multi-objective fisheries environment – Lessons from the North Sea. *Marine Policy*, *69*, 146–158. https://doi.org/10.1016/j.marpol.2016.04.012

Kraak, S. B. M., Bailey, N., Cardinale, M., Darby, C., De Oliveira, J. A. A., Eero, M., Graham, N., Holmes, S. J., Jakobsen, T., Kempf, A., Kirkegaard, E., Powell, J., Scott, R. D., Simmonds, E. J., Ulrich, C., Vanhee, W., & Vinther, M. (2013). Lessons for fisheries management from the EU cod recovery plan. *Marine Policy*, *37*(1), 200–213. https://doi.org/10.1016/j.marpol.2012.05.002

Krag, L. A., Herrmann, B., Feekings, J., & Karlsen, J. D. (2016). Escape panels in trawls-a consistent management tool? *Aquatic Living Resources*. https://doi.org/10.1051/alr/2016028

Larkin, P. a. (1977). An Epitaph for the Concept of Maximum Sustained Yield. *Transactions of the American Fisheries Society*, *106*(1), 1–11. https://doi.org/10.1577/1548-8659(1977)106<1:AEFTCO>2.0.CO;2

Laurec, A., Biseau, A., & Charuau, A. (1991). Modelling technical interactions. *ICES Marine Science Symposia*, *193*, 225–236.

Lewy, P., & Vinther, M. (2004). A stochastic age–length-structured multispecies model applied to North Sea stocks. *ICES Document CM 2004/FF: 20*.

Link, J. S., Huse, G., Gaichas, S., & Marshak, A. R. (2020). Changing how we approach fisheries: A first attempt at an operational framework for ecosystem approaches to fisheries management. *Fish and Fisheries*, *21*(2), 393–434. https://doi.org/10.1111/faf.12438

Link, J. S., Kohler, B., Griffis, R., Brady, M. M. P., Ito, S.-I., Garçon, V., Hollowed, A., Barange, M., Brown, R., & Wawrzynski, W. (2018). A graphic novel from the 4th International Symposium on the Effects of Climate Change on the World's Oceans. *ICES Journal of Marine Science*. https://doi.org/10.1093/icesjms/fsy155

Lotze, H. K., Tittensor, D. P., Bryndum-Buchholz, A., Eddy, T. D., Cheung, W. W. L., Galbraith, E. D., Barange, M., Barrier, N., Bianchi, D., Blanchard, J. L., Bopp, L., Büchner, M., Bulman, C. M., Carozza, D. A., Christensen, V., Coll, M., Dunne, J. P., Fulton, E. A., Jennings, S., … Worm, B. (2019). Global ensemble projections reveal trophic amplification of ocean biomass declines with climate change. *Proceedings of the National Academy of Sciences*, *116*(26), 12907–12912. https://doi.org/10.1073/pnas.1900194116

Mace, P. M. (2001). A new role for MSY in single-species and ecosystem approaches to fisheries stock assessment and management. *Fish and Fisheries*, *2*(1), 2–32. https://doi.org/10.1046/j.1467-2979.2001.00033.x

Marchal, P. (2008). A comparative analysis of metiers and catch profiles for some French demersal and pelagic fleets. *ICES Journal of Marine Science*, *65*(4), 674–686. https://doi.org/10.1093/icesjms/fsn044

Mariani, G., Cheung, W. W. L., Lyet, A., Sala, E., Mayorga, J., Velez, L., Gaines, S. D., Dejean, T., Troussellier, M., & Mouillot, D. (2020). Let more big fish sink: Fisheries prevent blue carbon sequestration—half in unprofitable areas. *Science Advances*, *6*(44), eabb4848. https://doi.org/10.1126/sciadv.abb4848

McQuaw, K., & Hilborn, R. (2020). Why are catches in mixed fisheries well below TAC? *Marine Policy*, *117*, 103931. https://doi.org/10.1016/j.marpol.2020.103931

Mesnil, B. (2012). The hesitant emergence of maximum sustainable yield (MSY) in fisheries policies in Europe. *Marine Policy*, *36*(2), 473–480. https://doi.org/10.1016/j.marpol.2011.08.006

Moore, C., Davie, S., Robert, M., Pawlowski, L., Dolder, P., & Lordan, C. (2019). Defining métier for the Celtic Sea mixed fisheries: A multiannual international study of typology. *Fisheries Research*. https://doi.org/10.1016/j.fishres.2019.105310

Mortensen, L. O., Ulrich, C., Eliasen, S., & Olesen, H. J. (2017). Reducing discards without reducing profit: free gear choice in a Danish result-based management trial. *ICES Journal of Marine*

*Science: Journal Du Conseil*, *74*(5), fsw209. https://doi.org/10.1093/icesjms/fsw209

Mortensen, L. O., Ulrich, C., Hansen, J., & Hald, R. (2018). Identifying choke species challenges for an individual demersal trawler in the North Sea, lessons from conversations and data analysis. *Marine Policy*, *87*, 1–11. https://doi.org/10.1016/j.marpol.2017.09.031

Mortensen, L. O., Ulrich, C., Olesen, H. J., Bergsson, H., Berg, C. W., Tzamouranis, N., & Dalskov, J. (2017). Effectiveness of fully documented fisheries to estimate discards in a participatory research scheme. *Fisheries Research*, *187*, 150–157. https://doi.org/10.1016/j.fishres.2016.11.010

Nielsen, K. N., Aschan, M. M., Agnarsson, S., Ballesteros, M., Baudron, A., Borges, M. de F., Campos, A., Chapela, R., Daníelsdóttir, A. K., Erzini, K., Gregersen, Ó., Holm, P., Lucchetti, A., Margeirsson, S., Mendes, H. V., Olsen, P., Rangel, M., Sala, A., Santiago, J. L., … Fernandes, P. G. (2018). A framework for results-based management in fisheries. *Fish and Fisheries*. https://doi.org/10.1111/faf.12257

Nielsen, K. N., Holm, P., & Aschan, M. (2015). Results based management in fisheries: Delegating responsibility to resource users. *Marine Policy*. https://doi.org/10.1016/j.marpol.2014.10.007

NSAC. (2017a). *NSAC Advice Ref. 08-1617. Implementation of the Landing Obligation; implications for Cod, Plaice, Saithe and Whiting in 2018*. http://www.nsrac.org/wp-content/uploads/2016/12/08-1617-Implementation-of-LO-Implications-for-cod-plaice-saithe-whiting-in-2018.pdf

NSAC. (2017b). *NSAC Advice Ref. 14-1617. Managing Fisheries within the Landing Obligation*. http://nsrac.org/wp-content/uploads/2016/12/14-1617-Managing-the-Fisheries-within-the-Landing-Obligation-1.pdf

O'Neill, F. G., Feekings, J., Fryer, R. J., Fauconnet, L., & Afonso, P. (2019). Discard Avoidance by Improving Fishing Gear Selectivity: Helping the Fishing Industry Help Itself. In *The European Landing Obligation* (pp. 279–296). Springer International Publishing. https://doi.org/10.1007/978-3-030-03308-8_14

Österblom, H., Sissenwine, M., Symes, D., Kadin, M., Daw, T., & Folke, C. (2011). Incentives, social-ecological feedbacks and European fisheries. *Marine Policy*, *35*(5), 568–574. https://doi.org/10.1016/j.marpol.2011.01.018

Pastoors, M. A. (2014). Exponential growth in the number of words used for the European Common Fisheries Policy (CFP): Does better management require more text? *Marine Policy*, *46*, 101–104. https://doi.org/10.1016/j.marpol.2014.01.008

Patrick, W. S., & Link, J. S. (2015). Hidden in plain sight: Using optimum yield as a policy framework to operationalize ecosystem-based fisheries management. *Marine Policy*, *62*, 74–81. https://doi.org/10.1016/j.marpol.2015.08.014

Penas Lado, E. (2016). The Common Fisheries Policy. In *Economic Affairs* (Vol. 37, Issue 1). John Wiley & Sons, Ltd. https://doi.org/10.1002/9781119085676

Pinsky, M. L., Eikeset, A. M., McCauley, D. J., Payne, J. L., & Sunday, J. M. (2019). Greater vulnerability to warming of marine versus terrestrial ectotherms. *Nature*, *569*(7754), 108–111. https://doi.org/10.1038/s41586-019-1132-4

Plet-Hansen, Kristian S., Bergsson, H., & Ulrich, C. (2019). More data for the money: Improvements in design and cost efficiency of electronic monitoring in the Danish cod catch quota management trial. *Fisheries Research*. https://doi.org/10.1016/j.fishres.2019.03.009

Plet-Hansen, Kristian S., Eliasen, S. Q., Mortensen, L. O., Bergsson, H., Olesen, H. J., & Ulrich, C. (2017). Remote electronic monitoring and the landing obligation – some insights into fishers' and fishery inspectors' opinions. *Marine Policy*, *76*, 98–106. https://doi.org/10.1016/j.marpol.2016.11.028

Plet-Hansen, Kristian S, Bastardie, F., & Ulrich, C. (2020). The value of commercial fish size distribution recorded at haul by haul compared to trip by trip. *ICES Journal of Marine Science*. https://doi.org/10.1093/icesjms/fsaa141

Plet-Hansen, Kristian Schreiber. (2020). *Fisheries data from electronic monitoring and traceability systems in the context of the EU landing obligationNo Title*.

Plet-Hansen, Kristian Schreiber, Larsen, E., Mortensen, L. O., Nielsen, J. R., & Ulrich, C. (2018). Unravelling the scientific potential of high resolution fishery data. *Aquatic Living Resources*, *31*, 24. https://doi.org/10.1051/alr/2018016

Pörtner, H., Roberts, D. C., Masson-Delmotte, V., Zhai, P., Tignor, M., Poloczanska, E., Mintenbeck, K., Algeria, A., Nicolai, M., Okem, A., Petzold, J., Rama, B., & Weyer, N. M. (2019). Summary for Policymakers. In: IPCC Special Report on the Ocean and Cryosphere in a changing Climate. *IPCC Report 2019*.

Probst, W. N. (2019). How emerging data technologies can increase trust and transparency in fisheries. *ICES Journal of Marine Science*. https://doi.org/10.1093/icesjms/fsz036

Quirijns, F., & Pastoors, M. (2014). *Discard Atlas of North Sea fisheries*. http://edepot.wur.nl/315708

Reid, D. G., Calderwood, J., Afonso, P., Bourdaud, P., Fauconnet, L., González-Irusta, J. M., Mortensen, L. O., Ordines, F., Lehuta, S., Pawlowski, L., Plet-Hansen, K. S., Radford, Z., Robert, M., Rochet, M.-J., Rueda, L., Ulrich, C., & Vermard, Y. (2019). The Best Way to Reduce Discards Is by Not Catching Them! In *The European Landing Obligation* (pp. 257–278). Springer International Publishing. https://doi.org/10.1007/978-3-030-03308-8_13

Rihan, D. (2018). *Research for PECH Committee - Landing Obligation and Choke Species in Multispecies and Mixed Fisheries - The North Western Waters*. https://doi.org/10.2861/346987

Rihan, D., Uhlmann, S. S., Ulrich, C., Breen, M., & Catchpole, T. (2019). Requirements for Documentation, Data Collection and Scientific Evaluations. In *The European Landing Obligation* (pp. 49–68). Springer International Publishing. https://doi.org/10.1007/978-3-030-03308-8_3

Rindorf, A., Dichmont, C. M., Levin, P. S., Mace, P., Pascoe, S., Prellezo, R., Punt, A. E., Reid, D. G., Stephenson, R., Ulrich, C., Vinther, M., & Clausen, L. W. (2017). Food for thought: pretty good multispecies yield. *ICES Journal of Marine Science: Journal Du Conseil*, *2016*, fsw071. https://doi.org/10.1093/icesjms/fsw071

Rindorf, A., Mumford, J., Baranowski, P., Clausen, L. W., García, D., Hintzen, N. T., Kempf, A., Leach, A., Levontin, P., Mace, P., Mackinson, S., Maravelias, C., Prellezo, R., Quetglas, A., Tserpes, G., Voss, R., & Reid, D. (2017). Moving beyond the MSY concept to reflect multidimensional fisheries management objectives. *Marine Policy*, *85*, 33–41. https://doi.org/10.1016/j.marpol.2017.08.012

Robert, M., Calderwood, J., Radford, Z., Catchpole, T., Reid, D. G., & Pawlowski, L. (2019). Spatial distribution of discards in mixed fisheries: species trade-offs, potential spatial avoidance and national contrasts. *Reviews in Fish Biology and Fisheries*, *29*(4), 917–934. https://doi.org/10.1007/s11160-019-09581-z

Russo, T., D'Andrea, L., Franceschini, S., Accadia, P., Cucco, A., Garofalo, G., Gristina, M., Parisi, A., Quattrocchi, G., Sabatella, R. F., Sinerchia, M., Canu, D. M., Cataudella, S., & Fiorentino, F. (2019). Simulating the Effects of Alternative Management Measures of Trawl Fisheries in the Central Mediterranean Sea: Application of a Multi-Species Bio-economic Modeling Approach. *Frontiers in Marine Science*. https://doi.org/10.3389/fmars.2019.00542

STECF. (2015). *Evaluation of management plans: Evaluation of the multi-annual plan for the North Sea demersal stocks (STECF-15-04)*. https://doi.org/EUR 27232 EN, JRC 95959

STECF. (2019). *The 2019 Annual Economic Report on the EU Fishing Fleet (STECF-19-06)*. https://stecf.jrc.ec.europa.eu/reports/economic/-/asset_publisher/d7Ie/document/id/2571197?inheritRedirect=false&redirect=https%3A%2F%2Fstecf.jrc.ec.europa.eu%3A443%2Freports%2Feconomic%3Fp_p_id%3D101_INSTANCE_d7Ie%26p_p_lifecycle%3D0%26p_p_state%3Dnormal

STECF. (2020). *Monitoring the performance of the Common Fishery Policy (STECF Adhoc-20-01)*. https://doi.org/10.2760/230469

Uhlmann, S. S., Ulrich, C., & Kennelly, S. J. (Eds.). (2019). *The European Landing Obligation*. Springer International Publishing. https://doi.org/10.1007/978-3-030-03308-8

Ulrich, C. (2016). *The discard ban and its impact on the MSY objective on fisheries-the North Sea*.

Ulrich, C. (2018). *Research for PECH Committee - Landing Obligation and Choke Species in Multispecies and Mixed Fisheries - The North Sea*.

Ulrich, C., Andersen, B. S., Sparre, P. J., & Nielsen, J. R. (2007). TEMAS: fleet-based bio-economic simulation software to evaluate management strategies accounting for fleet behaviour. *ICES Journal of Marine Science*, *64*, 647–651. https://doi.org/10.1093/icesjms/fsm044

Ulrich, C., Le Gallic, B., Dunn, M. R., & Gascuel, D. (2002). A multi-species multi-fleet bioeconomic simulation model for the English Channel artisanal fisheries. *Fisheries Research*, *58*(3), 379–401. https://doi.org/10.1016/S0165-7836(01)00393-9

Ulrich, C., Olesen, H. J., Bergsson, H., Egekvist, J., Håkansson, K. B., Dalskov, J., Kindt-Larsen, L., & Storr-Paulsen, M. (2015). Discarding of cod in the Danish Fully Documented Fisheries trials. *ICES Journal of Marine Science: Journal Du Conseil*, *72*(6), 1848–1860. https://doi.org/10.1093/icesjms/fsv028

Ulrich, C., Pascoe, S., Sparre, P. J., Wilde, J.-W. De, & Marchal, P. (2002). Influence of trends in fishing power on bioeconomics in the North Sea flatfish fishery regulated by catches or by effort quotas. *Canadian Journal of Fisheries and Aquatic Sciences*, *59*(5), 829–843. https://doi.org/10.1139/f02-057

Ulrich, C., Reeves, S. a., Vermard, Y., Holmes, S. J., & Vanhee, W. (2011). Reconciling single-species TACs in the North Sea demersal fisheries using the Fcube mixed-fisheries advice framework. *ICES Journal of Marine Science*, *68*(7), 1535–1547. https://doi.org/10.1093/icesjms/fsr060

Ulrich, C., Vermard, Y., Dolder, P. J., Brunel, T., Jardim, E., Holmes, S. J., Kempf, A., Mortensen, L. O., Poos, J.-J., & Rindorf, A. (2017). Achieving maximum sustainable yield in mixed fisheries: a management approach for the North Sea demersal fisheries. *ICES Journal of Marine Science: Journal Du Conseil*, fsw126. https://doi.org/10.1093/icesjms/fsw126

Ulrich, C., Wilson, D. C. K., Nielsen, J. R., Bastardie, F., Reeves, S. a., Andersen, B. S., & Eigaard, O. R. (2012). Challenges and opportunities for fleet- and métier-based approaches for fisheries management under the European Common Fishery Policy. *Ocean and Coastal Management*, *70*, 38–47. https://doi.org/10.1016/j.ocecoaman.2012.06.002

van Helmond, A. T. M., Mortensen, L. O., Plet-Hansen, K. S., Ulrich, C., Needle, C. L., Oesterwind, D., Kindt-Larsen, L., Catchpole, T., Mangi, S., Zimmermann, C., Olesen, H. J., Bailey, N., Bergsson, H., Dalskov, J., Elson, J., Hosken, M., Peterson, L., McElderry, H., Ruiz, J., … Poos, J. J. (2020). Electronic monitoring in fisheries: Lessons from global experiences and future opportunities. *Fish and Fisheries*. https://doi.org/10.1111/faf.12425

van Hoof, L., Kraan, M., Visser, N. M., Avoyan, E., Batsleer, J., & Trapman, B. (2019). Muddying the Waters of the Landing Obligation: How Multi-level Governance Structures Can Obscure Policy Implementation. In *The European Landing Obligation* (pp. 179–196). Springer International Publishing. https://doi.org/10.1007/978-3-030-03308-8_9

Zeller, D., Cashion, T., Palomares, M., & Pauly, D. (2018). Global marine fisheries discards: A synthesis of reconstructed data. *Fish and Fisheries*, *19*(1), 30–39. https://doi.org/10.1111/faf.12233

Zimmermann, C., Kraak, S., Krumme, U., Santos, J., Stotera, S., & Nordheim, L. (2015). *Research for PECH Committee - options of handling choke species in the view of the EU landing obligation – the Baltic plaice example*.

# ANNEXES

# Annex 1: Summary facts of my scientific activity

## Research

- ICES Outstanding Achievement Award, 2020
- Appointed Professor in Fisheries Management, Technical University of Denmark (DTU Aqua) in 2015
- Participation in 17 international (EU funded) and 9 national (European Fisheries Fund – EFF/EMFF - funded) research projects (*see project details in section 8*). Has always been fully externally financed by projects.
- International coordinator for one H2020 project (2015-2019). International coordinator of a proposal in FP7 (in 2013, not funded).
- Participation to the elaboration and writing of 18 project proposals, 14 of which successfully funded
- WP leader for 5 of the EU funded international projects, and for 5 of the national projects
- 56 published ISI references, 30 presentations to international conferences including 22 with proceedings (*see publications details in section 10*)
- Regular reviewer for a number of journals (50+ reviews), mainly ICES Journal of Marine Science, Fisheries Research and Aquatic Living Resources.
- Occasional reviewer of research proposals.
- Co-Convener of a Theme Session in ICES Annual Science Conference in 2014, 2016 and 2018
- Member of the research evaluation team for the IFREMER station in Boulogne-sur-Mer in 2012
- Best Newcomer Award, ICES Annual Science Conference 1999

## Advice and support to public authorities

### Main activity in ICES (International Council for the Exploration of the Sea)

ICES is the Regional Fisheries Management Organisation that provides biological management advice for the NorthEast Atlantic, from Iceland to the Baltic Sea. It is also a network of more than 4000 scientists from almost 300 institutes, which organizes almost 150 experts and working groups per year on a great diversity of topics related to the marine environment (www.ices.dk). There, I have been mainly involved in the activities linked to stock assessment and management advice:

- WGNSSK (Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak). Member 2001-2019, Chair in 2010-2013
- WGMIXFISH (Working Group on Mixed Fisheries Advice) and related workshops and study groups. Main developer since 2006, Chair in 2009
- WGCHAIRS (Annual Meeting of Assessment Working Groups Chairs), 2009-2013
- WKIDP (Workshop on Integrated DATRAS products), Chair in 2014 *[DATRAS= online database of scientific sea surveys data]*
- Participation to Advice drafting for the North Sea EcoRegion and for several EU-Norway requests to ICES
- Participation into numerous additional workshops

### Main activity in STECF (EU Scientific, Technical and Economic Committee for Fisheries)

STECF is a an advisory body from the European Commission, regularly consulted on matters pertaining to the conservation and management of living aquatic resources, including biological, economic, environmental, social and technical considerations (https://stecf.jrc.ec.europa.eu/). STECF holds 25 experts meetings per year, and its final advice is emitted by the Plenary Committee of 30-35 members. These members are selected and appointed personally by the Commission for a duration of three years. I am very actively involved in this committee:

- Chair of the STECF plenary group of appointed experts since 2016, re-elected in 2019. Member since 2010 (on reserve list 2008-2010)
- Chair of the Expert Working Groups on the effort management regime for the Western Mediterranean Sea, 2018-2020
- Member of Expert WG on the evaluation of effort management regime, 2007-2015
- Member of Expert WG on the evaluation of multi-annual management plans, 2011-2015
- Member of Expert WG on landing obligation, 2013-2015

### Others

- Regular participation to the Danish forum on the new Common Fisheries Policy (CFP-Dialogforum, 2015-2018), a (bi-)monthly information group organized by the Danish Ministry of Food, Agriculture and Fisheries with representative stakeholders at national scale
- Regular contribution to the DTU Aqua Advice committee
- Numerous participations and presentations to meetings of the Regional Advisory Councils (RACs, EU trans-national stakeholders advisory groups gathering representatives from the fishing industry and NGOs) for the North Sea (NSRAC), and occasionally for the Baltic Sea (BSRAC) and Pelagic (Pelagic RAC)
- Participation and presentations to the DTU Aqua dialogue meetings on ICES advice

## Education

- Supervision of 1 post-doc and 2 PhD Students in Denmark *(see students details in section 9)*
- Supervision of 7 master projects and 2 bachelor projects
- Scientific opponent for 5 PhDs, of which 3 in France
- co-responsible for a DTU MSc course (5 ECTS) dealing with management and modelling of fisheries systems, annually since 2011
- 2-days course on MSY and MSY ranges given to European Commission (2016) and European Parliament (2017)
- 3-days FLR (Fisheries Laboratory in R) course given in 2009 and 2012
- U-DTU Teaching Level 1, Technical University of Denmark

# Annex 2 : My projects

## EU Funded projects[36]

1. **DiscardLess** (H2020, 2015-2019): Strategies for the gradual elimination of discards in European fisheries. Evaluated with possible note 15/15, overall coordinator. Total budget 5M Euros, 31 partners. Coordinator: DTU Aqua (DK). My role: Project coordinator
2. **PROBYFISH** (EU EASME, 2018-2021): Protecting bycaught species in mixed fisheries, 2018-2021. 6 partners. Coordinator: DTU Aqua (DK). My role: PI, contribution to proposal writing
3. **MYFISH** (FP7, 2012-2016): Maximising yield of fisheries while balancing ecosystem, economic and social concerns,. 6.5MEuros, 31 partners. Coordinator: DTU Aqua (DK). My role: PI, contribution to proposal writing
4. **SOCIOEC** (FP7, 2012-2015), Socio economic effects of management measures of the future CFP. 3.8 MEuros, 25 partners. Coordinator: TI Institute of Sea Fisheries (GE). My role: PI in North Sea case study, contribution to proposal writing
5. **VECTORS** (FP7, 2011-2015): Vectors of Change in Oceans and Seas Marine Life, Impact on Economic Sectors. 16 MEuros, 39 partners. Coordinator: Plymouth Marine Laboratory (UK). My role : minor supplier of bio-economic results
6. **VMSTools (Tender** MARE/2008/10 Lot 2, 2008-2011): Development of tools for logbook and VMS data analysis. 700 000 Euros. Coordinator: IMARES (NL). My role: PI, contribution to proposal writing.
7. **PBox (Tender** MARE/2008/10 Lot 3, 2009-2010**):** Study for the revision of the plaice box. 4 partners. Coordinator: IMARES (NL). My role: minor contributor, data provider.
8. **GAP1-2** (FP7, 2008-2009)**:** Bridging the gap between science and stakeholders. Phase 1, 800 000 Euros. Coordinator: CEFAS (UK). My role: participant in Danish case study.
9. **JAKFISH** (FP7, 2008-2011): Judgement and Knowledge in Fisheries including Stakeholders. 3.6 MEuros, 10 partners. Coordinator: IMARES (NL). My role: national project coordinator, leader of Synthesis WP, contribution to proposal writing
10. **AFRAME** (FP6, 2007-2009): A framework for fleet and area based fisheries management. 2.3 MEuros, 11 partners. Coordinator: AZTI (SP). My role: national project coordinator, leader of modelling WP and main model developer, contribution to proposal writing
11. **CEVIS** (FP6, 2005-2008): Comparative evaluations of innovative solutions in European fisheries management. 1.8 MEuros, 14 partners. Coordinator: IFM (DK). My role: PI
12. **EFIMAS** (FP6, 2004-2008): Operational evaluation tools for fisheries management options, 4.5 M Euros, 30 partners. Coordinator : DTU Aqua (DK). My role: I overtook the coordination of the modelling WP
13. **COMMIT** (FP6, 2004-2007): Creation of Multiannual Management Plans for Commitment. 1.4 MEuros, 11 partners. Coordinator: CEFAS (UK). My role: National coordinator, contribution to proposal writing
14. **TECTAC** (FP5, 2002-2005): Technical developments and tactical adaptations of important EU fleets, 3.2 MEuros. Coordinator : IFREMER (FR). My role: PI
15. **MATES (FISH/2001/02, 2001)**: Studies and support services related to the common fisheries policy - 2001 - Group 2 : Lot 2 - Analysis of possibilities of limiting

[36] Information on all these EU projects is available at http://cordis.europa.eu/projects/home_en.html

the annual fluctuations in TACs, 2001-2003. Coordinator: CEFAS (UK). My role: National coordinator

16. **FER** (DGMare, 2000-2001): Fishing Effort Relationship. Coordinator: DTU Aqua (DK). My role: Post-Doc
17. **CBFM** (FP5, 1996-2000): Bioeconomic modelling of the fisheries of the English channel. 680 000 Euros. Coordinator: University of Portsmouth (UK). My role: PhD student.

## National EMFF/EFF projects

18. **MINIDISC**: Minimising discards in Danish fisheries, 2014-2015. My role: Project coordinator, proposal writing
19. **FAST TRACK I** Sustainable, cost effective and responsive gear solutions under the landing obligation. My role: participant
20. **DEL-TORSK**: Optimal sustainable use of cod stocks available for Danish fisheries, 2014-2015. My role: Analysis of North Sea cod data and linkages with ICES assessment, proposal writing
21. **MSC certification of the plaice fishery in area IIIa** – basic investigations and development of a management model. 2012-2014. My role: leader of synthesis and management WPs, contribution to proposal writing.
22. **Eco-certification of Danish fisheries**. 2010-2013. My role: Principal developer, contribution to proposal writing
23. **URSIN**: Development of a method for long term spatially resolved management of the herring fishery in the North Sea and IIIa taking the migration of the primary herring stocks, the fishery pattern and by-catch of mackerel into consideration. 2009-2011. My role: participant and modeler.
24. **Improved advice** for the plaice stock in the Skagerrak and Kattegat (ICES area IIIa), 2005-2007. My role: PI, contribution to proposal writing
25. **Improved advice** for the mixed herring stocks in the Skagerrak and Kattegat (ICES area IIIa), 2005-2007. My role: participant and modeler.
26. **TEMAS**, Technical measures—Development of evaluation model and application in Danish fisheries. 2004-2007. My role: participant and modeler

# Annex 3 : Students supervision

Over the years, I have supervised a number of students, who have all well made their way after having worked with me, most of them having stayed in academia and holding permanent positions in research institutes.

## Postgraduates (PhD and postdocs)

- **Kristian Schreiber Plet-Hansen,** DTU Aqua (DK). *Fisheries data from electronic monitoring and traceability systems in the context of the EU landing obligation*. PhD defended in January 2020. Now employed at the Danish ministry for fisheries, previously employed at DTU Aqua. My role: Main supervisor (60%). Other supervisors: J. Rasmus Nielsen (20%); Francois Bastardie (20%). PhD Publications #18, 19, 24, 25, 28, 33
- **Lars Olof Mortensen,** DTU Aqua (DK), Post-doc (2015-2017). Now Spatial ecologist at DHI, Denmark. My role: Main supervisor (100%). Postdoc publications #17, 30, 34, 35
- **Bo Sølgaard Andersen**, Aalborg University (DK). *Short term behaviour of commercial fishers: a case study of the Danish mixed fisheries*. PhD defended in 2011, now Senior statistical programmer in Novo Nordisk. My role: co-supervisor (50%). Other supervisors Per J. Sparre (25%), J. Rasmus Nielsen (25%). PhD Publications #7, 11, 12, 41, 46.

## Master theses

- **Kristian Schreiber Plet-Hansen,** 2016. *How can Remote Electronic Monitoring help in the implementation of the Landing Obligation?*.
- **Karolina Molla Gazi**, 2017. *Stock assessment in the Western and Central Mediterranean Sea: Analysis of data quality and exploration of different stock assessment models*. Karolina is now scientist at WUR Marine Research institute, NL
- **Nikolaos Tzamouranis**, 2015. *Fine Scale Mapping of Cod Aggregations using High Resolution Fisheries Data.* Nikolaos is now Biological Controller at Arnarlax in Iceland. Publication #35
- **Søren Lorenzen Post**, 2012: *Can the mixing of herring stocks between the Baltic Sea and the North Sea be quantified from existing otolith data?*. Søren is now PhD student at DTU Aqua.
- **Alan Baudron**, 2007: *Evaluation of effort-based management in the Faroe Plateau cod fisheries: comparison with TAC management using FLR*. Alan has now a PhD and is scientist at University of Aberdeen, UK. Publication #49
- **Katell Hamon**, 2006: *Improvement of Assessment of Plaice in Illa*. Katell has now a PhD and is scientist at LEI, Netherlands
- **Youen Vermard**, 2004: *Evaluation of the generic multi-species multi-fleet simulation model TEMAS, and application to the Danish plaice fishery in the Kattegat and Skagerrak*. Youen has now a PhD and is scientist at IFREMER, France. Ongoing collaborations with him since then. Publication #46.

## Bachelor theses

- **Quentin LeBras**, 2012. *Synthesis redaction about plaice (Pleuronectes platessa) for the Marine fish atlas of Denmark*. Quentin is marketing advisor at Via Aqua, Nantes.
- **Paul Gatti**, 2011 : *Source of uncertainties in the catch at age matrix of the IIIa plaice stock.* Paul has now a PhD and is Post-doc at Memorial University of Newfoundland, Canada.

## Opponent at PhD Defences

- **Manuel Bellanger,** Ifremer, France. *Modelling institutional arrangements and bio-economic impacts of catch share management systems. Application to the Bay of Biscay sole fishery.* PhD defended 18-05-2017. Manuel is now scientist in Ifremer, France.
- **Juliette Alemany,** Ifremer, France. *Development of a Bayesian framework for data-limited stock assessment methods with two case studies: cuttlefish (Sepia officinalis) and pollack (Pollachius pollachius)*. President of committee. PhD defended 16-10-2017. Juliette is now Project Development Manager and Data scientist at Verifik8, France.
- **Jürgen Batsleer, WUR, Netherlands.** *Fleet dynamics in a changing policy environment.* PhD defended in 2016. Jürgen is now researcher at WUR, NL
- **Sarah Davie**, GMIT, Ireland. *The Drivers and Dynamics of Fisher Behaviour in Irish Fisheries.* PhD defended in 2013. Sarah is now scientist at WWF, UK.
- **Sigrid Lehuta**, AgroCampus Ouest, France. *Impact des mesures de gestion sur la dynamique de la pêcherie pélagique du golfe de Gascogne : Quelles certitudes ? Quels descripteurs?* PhD defended in 2010. Sigrid is now scientist at IFREMER, France.

# Annex 4: My publications

internet links:

**ORCID** : [0000-0001-7598-2051]

IFREMER : https://annuaire.ifremer.fr/cv/26344/

DTU Aqua :

http://www.dtu.dk/english/service/phonebook/person?id=39794&tab=2&qt=dtupublicationquery

Google scholar : https://scholar.google.com/citations?user=A086cXkAAAAJ&hl=fr

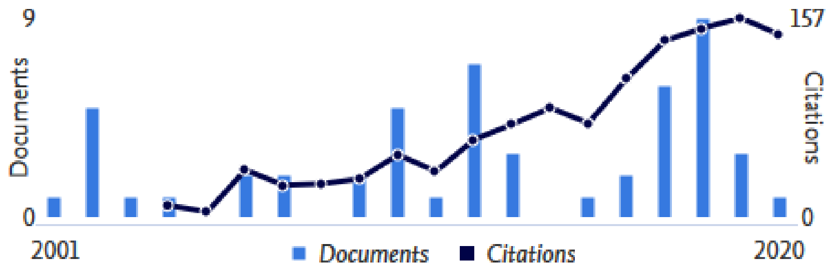



Fig 1. Scopus number of citations by year. https://www.scopus.com/authid/detail.uri?authorId=7101943343, accessed 29/10/2020.

Since the end of my PhD in 2000 I have had a regular production of scientific peer-reviewed papers and conference contributions (except for the years around my three maternity leaves). Particularly since 2010, the number of contributions and citations has been increasing (Fig1), reflecting the maturation and the influence of my research, and the spread of my reputation. At the end of 2020, Google Scholar gives me an h-index of 25[37], Scopus and WoS an index of 23.

My publication list is detailed below. I have published 14 first-author and 10 second-author peer-reviewed publications in 20 years. The three oldest second-author publications come from my own time as Post-doc scientist. Six others are first authored by students and young scientists (PhD; postdoc) that I have closely supervised. I have edited an open access book together with two co-editors, and published 3 synthesis reports for the European Parliament (two as sole author, one as second author).

Additionally, I have co-authored 28 other publications, on a variety of topics and with a great diversity of co-authors (often given in alphabetical order). Several of these publications are typical outcomes of EU projects with studies being performed across areas and case studies, or synthesis papers from workshops or specific studies. But noticeably, a number of these papers are also the fact of other people having used or expanded my Fcube model.

Finally, I have always given a high priority to scientific conferences, and above all to the ICES Annual Science Conference, which I have attended and contributed to almost every year. This conference is particularly important to me, not only because this is an excellent occasion for meeting with many nice colleagues, but also because sending an abstract for

[37] http://scholar.google.com/citations?user=A086cXkAAAAJ&hl=fr

this conference acts very much as a motivating first milestone that leads to scientific publications afterwards.

I provide here only the list of peer-reviewed publications and conference proceedings. The many reports, including ICES and STECF working  groups reports, project deliverables and projects final reports I also contributed to are not listed here (partly because I realized I did not always consistently record them…).

Last update 29/10/2020

## Publications as first author (chronological order)


1. Ulrich C. 2018. Research for PECH Committee - Landing Obligation and Choke Species in Multispecies and Mixed Fisheries - the North sea. European Parliament, 63 p.
2. Ulrich, C, Vermard Y., Dolder P. J., Brunel T., Jardim E., Holmes S.J., Kempf A., Mortensen L.O., Poos J.J., and Rindorf A. 2017. Achieving MSY in mixed fisheries. A proposed approach applied to the North Sea demersal fisheries. ICES Journal of Marine Science. DOI: 10.1093/icesjms/fsw126
3. Ulrich C. 2016. The discard ban and its impact on the MSY objective on fisheries-the North Sea. In Research for PECH Commitee - the discard ban and its impact on the maximum sustainable yield objective on fisheries. European Union. pp. 9-81. Available from: 10.2861/51629, 10.2861/994117
4. Ulrich, C., Hemmer-Hansen, J., Boje, J., Christensen, A., Hüssy, K.; Clausen L.W. 2016. Variability and connectivity of plaice populations from the Eastern North Sea to the Baltic Sea, Part II. Biological evidence of population mixing. Journal of Sea Research, vol 120, pp. 13-23. DOI: 10.1016/j.seares.2016.11.002.
5. Ulrich, C, Olesen, HJ, Bergsson, H, Egekvist, J, Håkansson, KB, Dalskov, J, Kindt-Larsen, L & Storr-Paulsen, M,. 2015. 'Discarding of cod in the Danish Fully Documented Fisheries trials' ICES Journal of Marine Science, vol 72, no. 6, pp. 1848-1860., doi 10.1093/icesjms/fsv028
6. Ulrich, C; Boje, J.; Cardinale, M.; Gatti, P.; le Bras, Q.; Andersen, M.; Hansen, J. H.; Hintzen, N.T.; Jacobsen, J. B.; Jonsson, P.; Miller, D. C.M.; Eg Nielsen, E.; Rijnsdorp, A. D.; Sköld, M.; Svedäng, H.; Wennhage, H., 2013. Variability and connectivity of plaice populations from the Eastern North Sea to the Western Baltic Sea, and implications for assessment and management. Journal of Sea Research, Vol. 84, 2013, p. 40-48.
7. Ulrich, C; Wilson, D. C.K.; Nielsen, J. R.; Bastardie, F.; Reeves, S. A.; Andersen, B. S.; Eigaard, O., 2012. Challenges and opportunities for fleet- and métier-based approaches for fisheries management under the European Common Fishery Policy. Ocean & Coastal Management, Vol. 70, p. 38-47.
8. Ulrich, C; Reeves, S. A.; Vermard, Y.; Holmes, S.; Vanhee, W. 2011. Reconciling single-species TACs in the North Sea demersal fisheries using the Fcube mixed-fisheries advice framework. ICES Journal of Marine Science, Vol. 68, No. 7, p. 1535-1547.
9. Ulrich, C; Wilson, D. C., 2009. Rights-based management and participatory governance in Southwest Nova Scotia. In: Comparative Evaluations of Innovatie Fisheries Management: Global Experiences and European Prospects. ed. / Kjellrun Hiis Hauge; Douglas Clyde Wilson. Dordrecht: Springer Science+Business Media B.V., p. 43-68. (Book chapter, authorship equal)
10. Ulrich, C; Reeves, S. A.; K., S.B.M.,2008. Mixed fisheries and the ecosystem approach. ICES Insight, Vol. 45, p. 36-39.
11. Ulrich, C; Andersen, B. S.; Sparre, P. J.; Nielsen, J. R., 2007. TEMAS: fleet-based bio-economic simulation software to evaluate management strategies accounting for fleet behaviour. ICES Journal of Marine Science, Vol. 64, No. 4, 2007, p. 647-651.
12. Ulrich, C; Andersen, B. S., 2004. Dynamics of fisheries, and the flexibility of vessel activity in Denmark between 1989 and 2001. ICES Journal of Marine Science, Vol. 61, No. 3, p. 308-322.
13. Ulrich, C; Le Gallic, B.; Dunn, M.R.; Gascuel, D., 2002. A multi-species multi-fleet bioeconomic simulation model for the English Channel artisanal fisheries. Fisheries Research, Vol. 58, No. 3, p. 379-401.
14. Ulrich, C; Pascoe, S.; Sparre, P. J.; de Wilde, J.-W.; Marchal, P., 2002. Influence of trends in fishing power on bioeconomics in the North Sea flatfish fishery regulated

by catches or by effort quotas. Canadian Journal of Fisheries and Aquatic Sciences, Vol. 59, No. 5, p. 829-843.
15. Ulrich, C; Marchal, P. 2002. Sensitivity of some biological reference points to shifts in exploitation patterns and inputs uncertainty for three North Sea demersal stocks. Fisheries Research, Vol. 58, No. 2, p. 153-169.
16. Ulrich, C; Gascuel, D.; Dunn, M.R.; Le Gallic, B.; Dintheer, C., 2001. Estimation of technical interactions due to the competition for resource in a mixed-species fishery, and the typology of fleets and metiers in the English Channel. Aquatic Living Resources, Vol. 14, No. 5, p. 267-281.

## Publications as co-author (chronological order)

### 2020

17. van Helmond, A. T. M., Mortensen, L. O., Plet-Hansen, K. S., Ulrich, C., Needle, C. L., Oesterwind, D., Kindt-Larsen, L., Catchpole, T., Mangi, S., Zimmermann, C., Olesen, H. J., Bailey, N., Bergsson, H., Dalskov, J., Elson, J., Hosken, M., Peterson, L., McElderry, H., Ruiz, J., ... Poos, J. J. 2020. Electronic monitoring in fisheries: Lessons from global experiences and future opportunities. *Fish and Fisheries*, *21*(1), 162-189. DOI: 10.1111/faf.12425
18. Calderwood, J., Plet-Hansen, K.S., Ulrich, C., Reid D. G. Fishing for Euros: How mapping applications can assist in maintaining revenues under the Landing Obligation. ICES Journal of Marine Science, In Press. DOI: 10.1093/icesjms/fsaa116
19. Plet-Hansen, K.S., Bastardie, F., & Ulrich, C. The value of commercial fish size distribution recorded at haul-by-haul compared to trip-by-trip. ICES Journal of Marine Science, In Press. DOI: 10.1093/icesjms/fsaa141

### 2019

20. Aranda M., Ulrich C., Le Gallic B., Borges L., Metz S., Prellezo R., Santurtun M. 2019. Étude pour PECH — La politique de la pêche de l'UE – dernières évolutions et défis à venir / Research for PECH Committee — EU fisheries policy – latest developments and future challenges. https://archimer.ifremer.fr/doc/00589/70087/
21. Eliasen, S. Q., Feekings, J. P., Krag, L. A., Malta, T. A. M. D. V., Mortensen, L. O., & Ulrich, C. 2019. The landing obligation calls for a more flexible technical gear regulation in EU waters - greater industry involvement could support development of gear modifications. Marine Policy, 99, 173-180. DOI : 10.1016/j.marpol.2018.10.020
22. Feekings, J. P., O'Neill, F. G., Krag, L. A., Ulrich, C., & Veiga Malta, T. 2019. An evaluation of European initiatives established to encourage industry-led development of selective fishing gears. Fisheries Management and Ecology, 26(6), 650-660. DOI : 10.1111/fme.12379
23. James, K. M., Campbell, N., Viðarsson, J. R., Vilas, C., Schreiber Plet-Hansen, K., Borges, L., González, Ó., Helmond, A. T. M. V., Pérez-Martín, R. I., Antelo, L. T., Pérez-Bouzada, J., & Ulrich, C. 2019. Tools and technologies for the monitoring, control and surveillance of unwanted catches. In S. Uhlmann, C. Ulrich, & S. Kennelly (Eds.), The European Landing Obligation : Reducing discards in complex, multi-species multi-jurisdictional fisheries (pp. 363-383). Springer Open. https://doi.org/10.1007/978-3-030-03308-8_18
24. Plet-Hansen, K. S., Bergsson, H., & Ulrich, C. 2019. More data for the money: Improvements in design and cost efficiency of electronic monitoring in the Danish cod catch quota management trial. Fisheries Research, 215, 114-122. DOI : 10.1016/j.fishres.2019.03.009
25. Reid, D. G., Calderwood, J., Afonso, P., Bourdaud, P., Fauconnet, L., González-Irusta, J. M., Mortensen, L. O., Ordines, F., Lehuta, S., Pawlowski, L., Schreiber

Plet-Hansen, K., Redford, Z., Robert, M., Rochet, M-J., Rueda, L., Ulrich, C., & Vermard, Y. 2019. The best way to reduce discards is by not catching them! In S. S. Uhlmann, C. Ulrich, & S. J. Kennelly (Eds.), The European Landing Obligation: Reducing Discards in Complex, Multi-Species and Multi-Jurisdictional Fisheries (pp. 257-278). Springer Open. https://doi.org/10.1007/978-3-030-03308-8_13
26. Rihan, D., Uhlmann, S. S., Ulrich, C., Breen, M., & Catchpole, T. 2019. Requirements for documentation, data collection and scientific evaluations. In S. S. Uhlmann, C. Ulrich, & S. J. Kennelly (Eds.), The European Landing Obligation: Reducing Discards in Complex, Multi-Species and Multi-Jurisdictional Fisheries (pp. 49-70). Springer Open. DOI : 10.1007/978-3-030-03308-8_3
27. Uhlmann, S. S., Ulrich, C., & Kennelly, S. J. (Eds.) 2019. The European Landing Obligation: Reducing Discards in Complex, Multi-Species and Multi-Jurisdictional Fisheries. Springer Open. DOI : 10.1007/978-3-030-03308-8

## 2018

28. Plet-Hansen, K. S., Larsen, E., Mortensen, L. O., Nielsen, J. R., & Ulrich, C. 2018. Unravelling the scientific potential of high resolution fishery data. Aquatic Living Resources, 31, [24]. DOI: 10.1051/alr/2018016
29. Nielsen, J. R., Thunberg, E., Holland, D. S., Schmidt, J. O., Fulton, E. A., Bastardie, F., ... Ulrich, C., Waldo, S. 2018. Integrated ecological-economic fisheries models - evaluation, review and challenges for implementation. Fish and Fisheries, 19(1), 1-29. DOI: 10.1111/faf.12232
30. Mortensen LO, Ulrich C, Hansen J, Hald R. 2018. Identifying choke species challenges for an individual demersal trawler in the North Sea, lessons from conversations and data analysis. Marine Policy. 87:1-11. DOI : 10.1016/j.marpol.2017.09.031
31. Jardim E, Eero M, Silva A, Ulrich C, Pawlowski L, Holmes SJ, Ibaibarriaga L, De Oliveira JAA, Riveiro I, Alzorriz N, Citores L, Scott F, Uriarte A, Carrera P, Duhamel E, Mosqueira I. 2018. Testing spatial heterogeneity with stock assessment models. P L o S One. 13(1). DOI : 10.1371/journal.pone.0190791

## 2017

32. Rindorf A, Dichmont CM, Levin PS, Mace P, Pascoe S, Prellezo R, Punt AE, Reid DG, Stephenson R, Ulrich C, Vinther M, Worsøe Clausen L. 2017. Food for thought: pretty good multispecies yield. ICES Journal of Marine Science. 74(2):475-486. DOI : 10.1093/icesjms/fsw071
33. Plet-Hansen, KS, Eliasen, SQ, Mortensen, LO, Bergsson, H, Olesen, HJ & Ulrich, C 2017, 'Remote electronic monitoring and the landing obligation – some insights into fishers' and fishery inspectors' opinions' Marine Policy, vol 76, pp. 98-106. DOI: 10.1016/j.marpol.2016.11.028
34. Mortensen, L. O., Ulrich, C., Eliasen, S.Q., & Olesen, H. J. (2017). Reducing discards without reducing profit: Free gear choice in a Danish result-based management trial. ICES Journal of Marine Science, 74(5), 1469-1479. DOI : 10.1093/icesjms/fsw209
35. Mortensen, LO, Ulrich, C, Olesen, HJ, Bergsson, H, Berg, CW, Tzamouranis, N & Dalskov, J (2017), Effectiveness of fully documented fisheries to estimate discards in a participatory research scheme. Fisheries Research, vol 187, pp. 150-157. DOI: 10.1016/j.fishres.2016.11.010

## 2016

36. Marchal, P., Andersen, J.L., Aranda, M., Fitzpatrick, M., Goti, L., Guyader, O., Haraldsson, G., Hatcher, A., Hegland, T.J., Le Floc'h, P., Macher, C., Malvarosa, L., Maravelias, C.D., Mardle, S., Murillas, A., Nielsen, J.R., Sabatella, R., Smith, A.D.M., Stokes, K., Thoegersen, T., Ulrich, C., 2016. A comparative review of fisheries management experiences in the European Union and in other countries worldwide: Iceland, Australia and New Zealand. Fish and Fisheries, vol 17, no. 3, pp. 803-824. DOI: 10.1111/faf.12147

37. Kempf A., Mumford J., Levontin P., Leach A., Hoff A., Hamon K.G., Bartelings, H., Vinther, M., Staebler, M., Poos, J.J., Smout, S., Frost, H., van den Burg, S., Ulrich, C., Rindorf, A.. The MSY concept in a multi-objective fisheries environment – lessons from the North Sea, Marine Policy, pp. 146-158. DOI: 10.1016/j.marpol.2016.04.012

## 2013

38. Beare, D.; Rijnsdorp, A. D.; Blæsbjerg, M.; Damm, U.; Egekvist, J.; Fock, H.; Kloppmann, M.; Röckmann, C.; Schroeder, A.; Schulze, T.; Tulp, I.; Ulrich, C.; Hal, R. van; Kooten, T. van; Verweij, M., 2013 Evaluating the effect of fishery closures: lessons learnt from the Plaice Box. Journal of Sea Research, Vol. 84, p. 49-60.
39. Kraak, S.B.M.; Bailey, N.; Cardinale, M.; Darby, C.; Oliveira, J.A.A.; Eero, Margit; Graham, N.; Holmes, S.; Jakobsen, T.; Kempf, A.; Kirkegaard, Eskild; Powell, J.; Scott, R.D.; Simmonds, E.J.; Ulrich, C.; Vanhee, W.; Vinther, Morten, 2013. Lessons for fisheries management from the EU cod recovery plan. Marine Policy, Vol. 37, p. 200-213.

## 2012

40. Deporte, N.; Ulrich, C.; Mahévas, S.; Demanèche, S.; Bastardie, F., 2012. Regional métier definition: A comparative investigation of statistical methods using a workflow applied to the international otter trawl fisheries in the North Sea. ICES Journal of Marine Science, Vol. 69, No. 2, 2012, p. 331-342.
41. Andersen, Bo S.; Ulrich, C.; Eigaard, O.; Chrisentensen, A.-S., 2012. Short-term choice behaviour in a mixed fishery: investigating métier selection in the Danish gillnet fishery. ICES Journal of Marine Science, Vol. 69, No. 1, p. 131-143.
42. Hintzen, N. T.; Bastardie, F.; Beare, D.; Piet, G. J.; Ulrich, C.; Deporte, N.; Egekvist, J.; Degel, H., 2012. VMStools: Open-source software for the processing, analysis and visualization of fisheries logbook and VMS data. Fisheries Research, Vol. 115-116, p. 31-43.
43. Iriondo, A. ; García, D.; Santurtún, M. ; Castro, J.; Quincoces, I.; Lehuta, S.; Mahévas, S. ; Marchal, P.; Tidd, A.; Ulrich, C. 2012 Managing mixed fisheries in the European western waters: application of Fcube methodology. Fisheries Research, Vol. 134-136, p. 6-16.
44. Maravelias, C.D.; Damalas, D.; Ulrich, C.; Katsanevakis, S.; Hoff, A. 2012 Multispecies fisheries management in the Mediterranean Sea: application of the Fcube methodology. Fisheries Management and Ecology, Vol. 19, No. 3, p. 189-199.
45. Röckmann, C.; Ulrich, C.; Dreyer, M.; Bell, E.; Borodzicz, E.; Haapasaari , P.; Hauge, K.H.; Howell, D.; Mantyniemi, S.; Miller, C.M.; Tserpes, G.; Pastoors, M. 2012 The added value of participatory modelling in fisheries management – what has been learnt?. Marine Policy, Vol. 36, No. 5, p. 1072-1085.

## 2010

46. Andersen, Bo S.; Vermard, Y.; Ulrich, C.; Hutton, T.; Poos, J-J. 2010 Challenges in integrating short-term behaviour in a mixed-fishery Management Strategies Evaluation frame: a case study of the North Sea flatfish fishery. Fisheries Research, Vol. 102, No. 1-2, p. 26-40.
47. Bastardie, F.; Nielsen, J. R.; Ulrich, C.; Egekvist, J.; Degel, H., 2010 Detailed mapping of fishing effort and landings by coupling fishing logbooks with satellite-recorded vessel geo-location. Fisheries Research, Vol. 106, No. 1, p. 41-53.
48. Bastardie, F.; Vinther, M.; Nielsen, J. R.; Ulrich, C.; Storr-Paulsen, Marie, 2010. Stock-based vs. fleet-based evaluation of the multi-annual management plan for the cod stocks in the Baltic Sea. Fisheries Research, Vol. 101, No. 3, p. 188-202.
49. Baudron, A.; Ulrich, C.; Nielsen, J. R.; Boje, J., 2010. Comparative evaluation of a mixed-fisheries effort-management system based on the Faroe Islands example. ICES Journal of Marine Science, Vol. 67, No. 5, p. 1036-1050.

50. Hoff, A.; Frost, H.; Ulrich, C.; Damalas, D.; Maravelias, C. D.; Goti, L.; Santurtun, M., 2010. Economic effort management in multispecies fisheries: the FcubEcon model. ICES Journal of Marine Science, Vol. 67, No. 8, p. 1802-1810.

## 2009

51. Bastardie, F.; Baudron, A.; Bilocca, R.; Boje, J.; Bult, T. P.; Garcia, D.; Hintzen, N. T.; Nielsen, J. R.; Petursdottir, G.; Sanchez, S.; Ulrich, C., 2009 Evaluating biological robustness of innovative management alternatives. Comparative Evaluations of Innovative Fisheries Management.. ed. / Kjellrun Hiis Hauge; Douglas Clyde Wilson. Dordrecht : Springer Science+Business Media B.V., p. 119-142.

## 2006

52. Kell, L.T.; Pilling, G.M.; Kirkwood, G.P.; Pastoors, M.A.; Mesnil, B.; Korsbrekke, K.; Abaunza, P.; Aps, R.; Biseau, A.; Kunzlik, P.; Needle, C.L.; Roel, B.A.; Ulrich, C. 2006 An evaluation of multi-annual management strategies for ICES roundfish stocks. ICES Journal of Marine Science, Vol. 63, No. 1, p. 12-24.
53. Marchal, P.; Andersen, Bo Sølgaard; Bromley, D.; Iriondo, A.; Mahevas, S.; Quirijns, F.; Rackham, B.; Santurtun, M.; Tien, N.; Ulrich, C., 2006 Improving the definition of fishing effort for important European fleets by accounting for the skipper effect. Canadian Journal of Fisheries and Aquatic Sciences, Vol. 63, No. 3, p. 510-533

## 2003

54. Marchal, P.; Ulrich, C.; Korsbrekke, K.; Pastoors, M.; Rackham, B. 2003 Annual trends in catchability and fish stock assessments. Scientia Marina, Vol. 67, No. Suppl. 1, p. 63-73.

## 2002

55. Marchal, P.; Ulrich, C.; Korsbrekke, K.; Pastoors, M.; Rackham, B. 2002 A comparison of three indices of fishing power on some demersal fisheries of the North Sea. ICES Journal of Marine Science, Vol. 59, No. 3, p. 604-623.
56. Marchal, P.; Ulrich, C.; Pastoors, M., 2002. Area-based management and fishing efficiency. Aquatic Living Resources, Vol. 15, No. 2, p. 73-85.

## Conferences papers


1. Ulrich, C. (2018). 3years in the landing obligation in Europe: Where do we stand, what have we learnt?. Paper presented at IIFET 2018, Seattle, United States.
2. Schreiber Plet-Hansen, K., Nielsen, J. R., & Ulrich, C. (2018). Fine-scale information on discard occurrence and catch composition by coupling EM and sea-packing commercial fishery data. Paper presented at ICES Annual Science Conference 2018, Hamburg, Germany.
3. Ulrich, C., Döring, R., Prellezo, R., & Vermard, Y. (2018). Mixed-fisheries management plans in Europe: Can we formulate a simple bioeconomic advice on a complex reality? Examples from the North Sea. Paper presented at IIFET 2018, Seattle, United States.
4. Ulrich, C. (2018). Scientific challenges and ways forward for fishing effort management regimes. Paper presented at FISHFORUM 2018, Rome, Italy.
5. Feekings, J. P., Krag, L. A., Malta, T. A. M. D. V., Ulrich, C., Mortensen, L. O., & Eliasen, S. (2017). FAST TRACK: Industry developed gear solutions under the landing obligation. Poster session presented at DanFish International, Aalborg, Denmark.
6. Ulrich. C. 2 years in the landing obligation in Europe: Where do we stand, what have we learnt? World Seafood Congress, Reykjavik
7. Jordan P. Feekings, Søren Qvist Eliasen, Ludvig Ahm Krag, Lars O. Mortensen, Tiago A. de Vega Malta, Clara Ulrich. 2016. Paths to enhance the development and the uptake of industry-led technical solutions to improved selectivity. IIFET, Aberdeen.
8. L.O. Mortensen, C. Ulrich, et al. 2016. A review of Remote Electronic Monitoring as a documentation tool. IIFET, Aberdeen
9. Anna Rindorf, Clara Ulrich 2016. Are FMSY ranges a promising or a dangerous option? ICES ASC
10. Ulrich, C. (2015). Fisheries Management: Is Europe turning the corner? In Book of Abstracts. DTU's Sustain Conference 2015 [F-6] Technical University of Denmark.
11. Ulrich C. 2015. Selectivity through target-based management and regulatory measures. Hearing at the European Parliament.
12. Schreiber Plet-Hansen, K., Ulrich, C., Olesen, H. J., Mortensen, L. O., & Bergsson, H. (2015). Fully documented fisheries - is remote electronic monitoring the future tool in fisheries control?. Poster session presented at ICES Annual Science Conference 2015, Copenhagen, Denmark.
13. Ulrich, C. (2015). H2020 DiscardLess (2015-2019): What can Science do to help with the Landings Obligation?. Poster session presented at ICES Annual Science Conference 2015, Copenhagen, Denmark.
14. Clara Ulrich, Ernesto Jardim (2015). Mixed-fisheries management plans in the frame of the new CFP: challenges in addressing more numerous and less well-defined policy objectives in a regional ecosystem-based approach. Experiences from the North Sea. EAFE conference.
15. Mortensen, L. O., Ulrich, C., Qvist Eliasen, S., Lund, H., Krag, L. A., Frandsen, R., Karlsen, J. D., Feekings, J. P., Olesen, H. J., & Dalskov, J. (2015). Kan frit redskabsvalg hjælpe når discardforbudet kommer?. Poster session presented at Internationale fiskerimesse, Aalborg, Denmark.
16. Ulrich, C., Manderson, J., Fitzpatrick, M., & Robins, R. (2015). Science-industry partnerships: The value of cooperative research in fisheries and marine

management. Paper presented at ICES Annual Science Conference 2015, Copenhagen, Denmark.
17. Condie, H. M., Dolder, P. J., Catchpole, T. L., Ulrich, C., & Grant, A. (2014). Incentivising selective fishing under catch quotas: using an FCube modelling approach to evaluate management options for North Sea mixed fisheries. Paper presented at ICES Annual Science Conference 2014, A Coruña, Spain.
18. Catchpole, T., Ulrich, C., & Rochet, M-J. (2014). Landings obligation as a pathway towards the integration of CFP and MSFD – lessons learned and forward look after 2015. Paper presented at ICES Annual Science Conference 2014, A Coruña, Spain.
19. Clara Ulrich, Paul Dolder, Ayoe Hoff, Alexander Kempf, Jan-Jaap Poos, Anna Rindorf, Youen Vermard. 2014. Achieving MSY and minimising conflicts in mixed-fisheries management. IIFET conference. Brisbane, Australia
20. Ulrich, Clara; Dalskov, Jørgen; Egekvist, Josefine; Håkansson, Kirsten Birch; Olesen, Hans Jakob; Storr-Paulsen, Marie, 2013. Behind the shine: An appraisal of five years of Danish CCTV trials. ICES ASC.
21. Feekings, Jordan P.; Poos, Jan Jaap; Aarts, Geert; Madsen, Niels; van Helmond, Edwin ; Catchpole, Tom; Rochet, Marie-Joelle; Pout, Alastair; Ulleweit, Jens; Vandemaele, Sofie; Ulrich, Clara, 2012. A wasted resource: cod discards in the North Sea. ICES CM. 2012/ C:31
22. Ulrich, Clara; Boje, Jesper; Cardinale, Massimiliano; Gatti, Paul; le Bras, Quentin; Andersen, Michael; Hansen, Jakob Hemmer; Hintzen, Niels T.; Jacobsen, Jonathan B.; Jonsson, Patrik; Miller, David C.M.; Eg Nielsen, Einar; Rijnsdorp, Adriaan; Svedäng, Henrik; Wennhage, Håkan, 2012. Improving the assessment and management of the plaice stock complex between the North Sea and the Baltic Sea. ICES CM 2012/N:02.
23. Pastoors, M.A.; Ulrich, Clara; Wilson, D.C.; Röckmann, C.; Goldsborough, D.; Degnbool, D.; Berner, L.; Johnson, T.; Haapasaari, P.; Dreyer, M.; Bell, E.; Borodzicz, E.; Hauge, K. Hiis; Howell, D.; Mäntyniemi, S.; Miller, D.; Aps, R.; Tserpes, G.; Kuikka, S.; Casey, J. 2012. JAKFISH Policy Brief: coping with uncertainty, complexity and ambiguity in fisheries management through participatory knowledge development. ICES CM 2012/L:16.
24. Holmes, Steven J.; Ulrich, Clara; Reeves, Stuart A., 2012. Mixed fisheries forecasts – lessons learned from their initial application to North Sea fisheries. ICES CM 2012/K:09.
25. Ulrich, Clara; Post, Søren Lorenzen; Worsøe Clausen, Lotte; Berg, Casper Willestofte; Deurs, Mikael van; Mosegaard, Henrik; Payne, Mark, 2012. Modelling the mixing of herring stocks between the Baltic and the North Sea from otolith data. ICES CM 2012/J:02.
26. Worsøe Clausen, Lotte; Mosegaard, Henrik; Berg, Casper Willestofte; Ulrich, Clara, 2012. The Gordian knot: managing herring (Clupea harengus) bridging across populations, fishery units, management areas, and politics. ICES CM. Vol. N:06
27. Röckmann, Christine; Hauge, Kjelrun Hiis; Ulrich, Clara; Bell, Ewen; Tserpes, George; Haapasaari, Päivi ; Mäntyniemi, Samu; Dreyer, Marion; Howell, Daniel; Borodzicz, Edward; Pastoors, Martin, 2011. Addressing uncertainty in fisheries management through participatory modelling.
28. Röckmann, Christine; Ulrich, Clara; Dreyer, Marion; Riis Hauge, Kjellrun; Borodzicz, Edward; Howell, Daniel; Bell, Ewen; Haapasaari, Päivi; Mäntyniemi, Samu; Tserpes, George; Pastoors, Martin, 2011. The added value of participatory modelling in fisheries management. What have we learned? ICES C.M. 2011/ P:04

29. Bastardie, Francois; Nielsen, J. Rasmus; Ulrich, Clara; Egekvist, Josefine; Degel, Henrik, 2010. Detailed mapping of fishing effort and landings by coupling fishing logbooks with satellite-recorded vessel geo-localisation. Poster session presented at Conference on Making the Most of Fisheries Information - Underpinning Policy, Management and Science, 23-26 Aug, Galway, Ireland, .
30. Ulrich, Clara; Coers, Aukje; Hauge, Kjellrun Hiis; Worsøe Clausen, Lotte; Olesen, Christian; Fisher, Lothar; Johansson, Reine; Payne, Mark / Improving complex governance schemes around Western Baltic Herring, throughthe development of a Long-Term Management Plan in an iterative process between stakeholders and scientists. In: ICES C.M 2010/P:07.
31. Hoff, A.; Frost, H.; Ulrich, Clara, 2009. An economic approach to overcoming over-quota catches in multi-species fisheries: The FcubEcon model. ICES C.M.2009/O:05
32. Ulrich, Clara; Wilson, D.C.; Nielsen, J. Rasmus; Reeves, S.A., 2009. Potentials and challenges in fleet- and métierbased approaches for fisheries management in the CFP. ICES C.M.. 2009/R:06
33. Ulrich, Clara; Garcia, D.; Damalas, D.; Frost, H.; Hoff, A.; HilleRisLambers, R.; Maravelias, C.; Reeves, S.A.; Santurtun, M., 2009. Reconciling single-species management objectives in an integrated mixed-fisheries framework for avoiding overquota catches. Main outcomes of the FP6 AFRAME project. ICES C.M. 2009/ M:08
34. Reeves, S.A.; Ulrich, Clara, 2007. Bridging the gap: fleets, fisheries and the ecosystem approach. In: ICES C.M. 2009
35. Hamon, Katell; Ulrich, Clara; Hoff, A.; Kell, L.T., 2007. Evaluation of management strategies for the North Sea roundfish fisheries with the FLR framework. MODSIM 2007 International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand, 2007. p. 2813-2819.
36. Kell, L.T.; Pilling, G.M.; Kirkwood, G.P.; Pastoors, M.; Mesnil, B.; Korsbrekke, K.; Abaunza, P.; Aps, R.; Biseau, A.; Kunzlik, P.; Needle, C.; Roel, B.A.; Ulrich, Clara, 2005. An evaluation of the implicit management procedure used for some ICES roundfish stocks. In: I C E S Journal of Marine Science, Vol. 62, No. 4, 2005, p. 750-759.
37. Marchal, P.; Andersen, Bo Sølgaard; Bromley, D.; Iriondo, A.; Mahévas, S.; Quirijns, F.; Rackham, B.; Santurtun, M.; Tien, N.; Ulrich, Clara, 2004. Linking fishing effort and fishing mortality in a mixed-fisheries context. In: ICES C.M. 2004/FF:27.
38. Sparre, Per Johan; Folmer, Ole; Ulrich, Clara, 2001. VPAbase : A prototype of database for storage and processing of vpa-input data. In: ICES C.M. 2001/P:23
39. Ulrich, Clara; Gascuel, D.; Bellail, R. 2000. Quantification de l’ importance des stocks locaux dans la Manche : Application du modèle In/Out à 7 stocks. Les espaces de l’ halieutique.: Proceedings of the 4th Forum Halieumétrique, Rennes, June 29-July 1, 1999. ed. / D. Gascuel; P. Chavance; N. Bez; A. Biseau. 2000. p. 125-146.
40. Ulrich, Clara; Gascuel, D.; Dunn, M., 1999. Analysis of the impact of fishing activities on exploited marine resources at the ecosystem scale: the case of English Channel fisheries. In: ICES C.M. 1999/Z:05,
41. Ulrich, Clara; Le Gallic, B.; Dunn, M.R. / Bioeconomic modelling of English Channel fisheries and their technical interactions: presentation of the simulation model BECHAMEL (BioEconomic CHAnnel ModEL). In: ICES C.M. 1999/ S:04

# Annex 5. My CV

**Europass Curriculum Vitae**

## Personal information

| | |
|---|---|
| Surname(s) / First name(s) | **Ulrich, Clara** |
| Nationality | French |
| Date of birth | 13.09.1974 |

## Work experience

| | |
|---|---|
| Dates | *Since 2019* |
| Occupation or position held | Deputy Head of Science |
| Main activities and responsibilities | Supporting scientific partnerships within and outside the institute in the field of fisheries science and marine ecology, and contributing to representing the institute in its interactions with society and public authorities |
| Name and address of employer | IFREMER, French National Institute for Ocean Science, Nantes, France |
| Dates | *2015-2019* |
| Occupation or position held | Professor in Fisheries Management |
| Main activities and responsibilities | Coordinator of H2020 DiscardLess http://www.discardless.eu/<br>Chair of EU Scientific, Technical and Economic Committee for Fisheries STECF.<br>Research on Common Fisheries Policy, discards, mixed fisheries, fleet dynamics;<br>Teaching a MSc course and student supervision. |
| Name and address of employer | DTU Aqua, Technical University of Denmark, Kemitorvet 201, 2800 Kgs Lyngby, Denmark |
| Dates | *2005-2014* |
| Occupation or position held | Senior Scientist |
| Main activities and responsibilities | Research on Management strategies evaluations, mixed fisheries, stock assessment, fleet dynamics; Major participation in International advice for fisheries management, Education. |
| Name and address of employer | DTU Aqua, Technical University of Denmark, Jægersborg Allé 1, 2920 Charlottenlund, Denmark |

| | |
|---|---|
| Dates | *2001-2005* |
| Occupation or position held | Scientist |
| Main activities and responsibilities | Management strategies evaluations, mixed fisheries, stock assessment, fleet dynamics. Major participation in International advice for fisheries management |
| Name and address of employer | Danish Institute for Fisheries Research, Jægersborg Allé 1, 2920 Charlottenlund, Denmark |
| Dates | *2000-2001* |
| Occupation or position held | Post-Doc |
| Main activities and responsibilities | Analysis of catchability and trends in fishing power for selected European fleets. |
| Name and address of employer | Danish Institute for Fisheries Research, Jægersborg Allé 1, 2920 Charlottenlund, Denmark |

## Awards

| | |
|---|---|
| 2020 | ICES Outstanding Achievement Award |
| 2019 | Chevalier de l'Ordre du Mérite Maritime (Contingent C) |
| 1999 | Best Newcomer Award, ICEs Annual Science Conference |

## Education and training

| | |
|---|---|
| Dates | *2000* |
| Title of qualification awarded | Ph.D. |
| Name and type of organisation providing education and training | ENSAR, National High School of Agronomy (Now Agrocampus Ouest), Rennes, France |
| Dates | *1996* |
| Title of qualification awarded | MSc |
| Name and type of organisation providing education and training | ENSAR, National High School of Agronomy (Now Agrocampus Ouest), Rennes, France |

**Personal skills and competences**

Language(s)

| (1=Fluent 5=Beginner) | Reading | Speaking | Writing |
|---|---|---|---|
| **French** | 1 | 1 | 1 |
| **English** | 1 | 1 | 1 |
| **Danish** | 1 | 1 | 1 |
| **Spanish** | 2 | 4 | 4 |

Other skills and competences

Social skills and competences:
Good experience in leadership and team work, panEuropean network including collaboration with and communication to managers and stakeholders (fishers, NGOs etc). Diplomatic skills; excellent communicator both orally and on text writing, including written policy advice.
4-days Teaching course (U-DTU Modul 1) attended in 2018
Organisational skills and competences:
International Coordinator of H2020 EU research project DiscardLess (4 years, 31 partners, 5 Millions Euros). Chair of EU STECF (Scientific, Technical and Economic Committee for Fisheries); Chair of ICES Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak 2010-2013. Coordinator of several work packages in European research projects, Coordinator of national EFF projects; organisation of few workshops, supervision of one PhD and some master students.
7-days Project leader course attended in 2010
Member of the Parents board of several associations in Denmark
Technical skills and competences:
20 years experience in the topics, Long membership of advice committees; 50+ peer review publications, numerous reports, presentations and working documents. Responsible of one 5 ECTS MSc course at DTU, additional teaching at DGMare in 2015 and in EU Parliament in 2016.
Good Computer skills and competences: Proficient use of R programing language.

| **Additional information** | **Detailed profile and full publication list available at**<br>https://annuaire.ifremer.fr/cv/26344/<br>https://www.dtu.dk/english/service/phonebook/person?id=39794&tab=2&qt=dtupublicationquery<br><br>**Selected Five Recent Publications**<br>van Helmond, A. T. M., Mortensen, L. O., Plet-Hansen, K. S., **Ulrich, C**., et al. 2020. Electronic monitoring in fisheries: Lessons from global experiences and future opportunities. Fish and Fisheries, 21(1), 162-189. DOI : 10.1111/faf.12425<br>Aranda M., **Ulrich C**., Le Gallic B., Borges L., Metz S., Prellezo R., Santurtun M. 2019. Research for EU Parliament PECH Committee — EU fisheries policy – latest developments and future challenges. https://archimer.ifremer.fr/doc/00589/70087/<br>Uhlmann, S. S., **Ulrich, C.**, & Kennelly, S. J. (Eds.). 2019. The European Landing Obligation: Reducing Discards in Complex, Multi-Species and Multi-Jurisdictional Fisheries. Springer Open. DOI 10.1007/978-3-030-03308-8<br>Plet-Hansen, K. S., Bergsson, H., & **Ulrich, C.** 2019. More data for the money: Improvements in design and cost efficiency of electronic monitoring in the Danish cod catch quota management trial. Fisheries Research, 215, 114-122. DOI 10.1016/j.fishres.2019.03.009<br>Mortensen LO, **Ulrich C,** Hansen J, Hald R. 2018. Identifying choke species challenges for an individual demersal trawler in the North Sea, lessons from conversations and data analysis. Marine Policy. 87:1-11. DOI: 10.1016/j.marpol.2017.09.031. |
|---|---|