**Integrating economics into fisheries science and advice: progress, needs and future opportunities**

**Supplementary material**

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# A - Summary sheets for each topic produced by the working group

## Total Allowable Catch (TAC) setting in output-based management systems

Total allowable catch limits (TAC) is one of the main fisheries management instruments in the ICES area. These are fundamental to output-based management systems, including under frameworks such as the EU Landing Obligation (LO)[[1]](#footnote-2). As a consequence, a large body of research exists and regular advice is produced regarding the economic impacts of implemented measures (Uhlmann et al., 2019). These impacts relate especially to the economic performance of fishing fleets, distributional effects of TAC management decisions (Bellanger et al., 2016, 2019; STECF, 2020) or changes in economic indicators relating to the dependency of the fleets on certain fish stocks/TACs (Carvalho et al., 2017; Santiago and Surís-Regueiro, 2018). They also relate to assessment of the use of fishing possibilities under TAC regulations and the LO, in terms of TAC uptake and incentives to discard/to high-grade (Villasante et al., 2016). Research also focuses on the evaluation of economic returns created under the existing Maximum Sustainable Yield (MSY) approach in management, compared to alternatives based on the Maximum Economic Yield (MEY) objective (i.e. measuring economic efficiency of current management, see e.g. Guillen et al., 2013; Emery et al., 2017).

In the EU, the advisory work is split between ICES and the Scientific Technical Economic Committee for Fisheries (STECF)[[2]](#footnote-3) with ICES primarily focused on biological impacts and to a limited extent impacts on the fleets (e.g. mixed-fisheries management advice), while STECF is specifically requested to address the social and economic impacts of long-term management plans. For the impact assessments, the economic data collected under the EU Data Collection Framework (DCF)[[3]](#footnote-4) is essential. These data are used in specific bio-economic models developed in most cases within large research projects funded by the European Commission Programs (e.g. VECTORS[[4]](#footnote-5), SOCIOEC[[5]](#footnote-6)) for certain fisheries, areas and management measures. The European Data Collection Framework provides funds to Member States to collect biological, economic and social data (STECF databases for economic information, Fisheries Dependent Information (FDI) for effort and landings, as well as social data[[6]](#footnote-7)) for the assessment of the Common Fisheries Policy (CFP). Other European institutional databases can also be used in these analyses (e.g. the European Market Observatory for fisheries and aquaculture[[7]](#footnote-8) or Eurostat[[8]](#footnote-9)). Similar methods, tools and data are used in the United States to produce assessments and advice on the definition of catch possibilities for fisheries where comprehensive economic data have been collected. NOAA is charged with collection of relevant data to support analysis of output-based management where FDI such as effort, landings, and revenues are routinely collected for most U.S. fisheries, which supports indicators of fishery performance for National[[9]](#footnote-10) and regional[[10]](#footnote-11) fisheries. NOAA also collects fishing vessel cost data for most major U.S. fisheries that is tailored to meet regional needs (Thunberg et al., 2015). These fisheries data, as well as the bioeconomic models mentioned above, constitute a strong basis for dealing with many of the research questions identified under the different topics.

## Mixed and multi-species fisheries management

Mixed (or multispecies) fisheries problems result from technical interactions and fishing behaviours driven (among others) by economic incentives where there are conflicting single-species sustainable levels of exploitation, different fleet-specific catchabilities for the target and by-catch species and different fishery targeting behaviours towards the different species. Integrating economic information, evaluation and considerations in the ICES mixed-fisheries management advice (ICES, 2020a) is therefore a major issue to account for ecological, social and economic trade-offs and management options, and to identify potential room of maneuver when setting sustainable TACs and trying to reconcile fishing possibilities across multiple fisheries and species.

Three categories of methods contribute to economic analyses of these mixed-fisheries problems and to the design of mixed fishery policies that depart from standard, single species management options. The first category relates to the assessment of the economic consequences of current management options and policies, and aims to highlight trade-offs in both the short- and the long-term using integrated economic-ecological scenario simulations (see e.g. Nielsen et al., 2018a for a review of applications). The second relates to economic optimization methods, for example seeking to identify strategies to achieve MEY (see e.g. Hoshino et al., 2018; Voss et al., 2014 or Lagarde et al., 2018 for applications). The third category relates to the application of multi-criteria assessment methods, such as viable control, to identify strategies that satisfy a set of ecological, social and economic constraints in a mixed-fisheries context (the so-called co-viability approach, see e.g. Gourguet et al., 2013; Doyen et al., 2017 or Briton et al., 2020 for applications).

Based on these methods, and relying on the same data as that used to inform stock-level TAC setting but split by fleets and fisheries (including via the definition of métiers), the following economic analyses are carried out to inform policy advice with regards to mixed-fisheries management:

(a) The evaluation of the effects of mixed catch composition is on-going, and provides clear policy advice on the consequences of technical interactions as several fleets and fisheries are exploiting the same stock, while at the same time exploiting different other stocks (see e.g. STECF, 2018). The importance of these interactions can be measured through the economic dependency of a fleet to a stock and through the fishing mortality a fleet contributes to a given stock. This can highlight the economic effects of the LO, including issues such as the existence of so-called “choke species” and perverse incentives such as high grading and targeting of weak stocks that can undermine management performance (see e.g. Batsleer et al., 2015; 2016, Holzer and DePiper, 2019).;

(b) Evaluation of the sustainability and distributional effects of different management options, according to biological indicators (single stock MSY targets and associated ranges, or multi-species MSY, see e.g. Ulrich et al., 2017; Rindorf et al., 2017) and to economic and social indicators (economic efficiency based on single- and multi-fleet MEY indicators, as well as variations in revenue, gross value-added or profit and/or employment, see e.g. Kempf et al., 2016; Garcia et al., 2020) is also available. These evaluations can also consider exploratory and goal-seeking (optimization) scenarios, including the current management principles according to the Precautionary Approach (PA) and single stock MSY quota settings, as well as other management options addressing, for example, multi-species management plans that also include non-fishery objectives (see e.g. Kellner et al., 2011; Sanchirico et al., 2021).

(c) Methods also enable evaluating the consequences of catch quota policies and informing their design. Catch quota allocation and distribution under TAC regulations is a major factor determining fishing behaviour in mixed-fisheries, in particular targeting, and fishery-level adaptations (See e.g. Marchal et al., 2011). To adequately capture the dynamics of this quota allocation and distribution, and its economic consequences, methods to understand the economic processes and associated key required economic information (including on quota pooling and quota swaps or trading) have been implemented (see e.g. Hoefnagel et al., 2017; ICES, 2021a; see also topic VII below). These enable evaluating the consequences of management options according to available fishing possibilities, flexibility in catchability and distributional effects given management and available fishing capacity at national, regional, harbor, fleet, fishery, producer organization/company and vessel levels (see e.g. Briton et al., 2021).

## Area-based and spatial management

Internationally, there has been a growing need for fisheries management to address the spatial dimensions of fishing and its interactions with ecosystems and other activities, raising the question of how economic research can contribute. Specific marine areas and habitats warrant special management due to their importance in terms of marine ecosystem biodiversity, functioning and services (see also topic XII). Additionally, interactions of fisheries with other marine sectors occupying marine areas and spatial allocations for other industries (e.g. aquaculture, energy, and transport) are increasingly being considered[[11]](#footnote-12). Infrastructure protection and safety reasons lead to more or less permanent fishing restrictions in the areas used for those alternative sectors, possibly changing biological production, biodiversity, and ultimately, fishing opportunities (Causon and Gill, 2018).

Spatial economic modelling approaches to fisheries management exist. The original economic literature on this topic applied econometric techniques to investigate spatial decisions of fishers (Wilen et al., 2002; van Putten et al., 2012; Girardin et al., 2017; Andrews et al., 2020; Dépalle et al., 2021). These models are particularly used in the context of evaluating the impacts of marine reserves, but the approach enables studying spatial management policies in general, namely the impacts on fishing costs and effort displacement resulting from alternative policies (e.g. Bastardie et al., 2014). This includes for example consideration of changing travel distances from port because of developments in travel pathways, or of changes in fishing location choices following changes in in fish population distributions (e.g. due to climate change).

There are several barriers to developing such integrated spatial management advice. Integrating the spatial dimension requires dealing with two types of dynamics: the spatial behaviour of fishers and spatially explicit fish population models. The applied literature, however, does not account for fish stock spatial dynamics and typically considers one target species only. Nielsen et al. (2018a) found that only 12 out of the 35 integrated models they included in their study had a spatial resolution sufficient to investigate sub-stock dynamics. Another barrier relates to the data needed as input for the models. To reach the adequate spatial scale to investigate area closures, individual and fine-scale spatial data are required, raising confidentiality issues.

Within ICES, several working groups touch on the evaluation of area-based management and spatial fisheries management options and performance. Among them, the Working Group on Fisheries Benthic Impact and Trade-offs (ICES, 2021b) focuses on fishing impacts on seafloor integrity from a spatial perspective, with support from the ICES Working Group on Spatial Fisheries Data[[12]](#footnote-13), which collects and analyzes spatial fisheries data. Such working groups help document the best places and timing for fishing gear restrictions as spatial management mitigation tools. Despite this, it appears that very few initiatives in ICES have sought to evaluate the performance of spatial management measures. This is true of biological studies (because applying the Before-After-Control-Impact design is a challenge in lack of true temporal baseline and counterfactuals, see Underwood, 1992). But evaluations of the economic impacts of spatial management options are even sparser, given the relatively recent focus in ICES on collecting and using economic and social data. This contrasts with other regions, where studies of the economic consequences of spatial management have been conducted and are being considered by advisory bodies (e.g. Abbott and Haynie, 2012; Bisack and Sutinen, 2006). In the context of ICES, recent ad hoc initiatives have considered the question of balancing spatially resolved environmental and fisheries economics considerations, for example in relation to the risks of habitat degradation[[13]](#footnote-14) (see e.g. Bastardie et al., 2020) and protective measures adopted as part of deep-sea access regulations[[14]](#footnote-15). However, to date, ICES has not implemented any advice that incorporates economic or social considerations on spatial fisheries management.

## Adjustment of capacity to resource potential

Knowing the level of catching capacity in a specific fishery (or country), and how this relates to the resources they target (current and potential levels), are fundamental pieces of information for fisheries management. In addition, managers need a clear understanding of the appropriate policy tools for adjusting capacity, how these can effectively be implemented, and the multiple (long- and short-term) trade-offs and risks associated with alternative choices (including welfare implications, as well as spill-over effects or problems related to the re-entry of fishing effort in a fishery). Combined, this information provides fishery managers with the knowledge required to make well-informed strategic decisions for improving fishery conditions, in terms of welfare and sustainability and meeting management objectives.

At present, ICES routinely undertakes stock specific assessments to determine reference points and advise on the levels of fishing mortality appropriate for achieving long-term management targets, such as MSY. Capacity in the fleets associated with these stocks and how that might best be adjusted to achieve these management targets is, however, currently not incorporated in either the assessment process or the advice ICES provides. This is despite the fact that capacity-related research has long been undertaken both within the ICES area and more broadly. In addition to defining the concept of capacity, questions economists have been working on, and can contribute to a better understanding of, predominantly fall into the areas of: assessing the adaptation of capacity to the resource potential, methods for adjusting capacity to match this potential, and identifying and incorporating the factors that may be influencing capacity (including policy).

Most work has been focused on static or dynamic assessments of fishing capacity (see e.g. Pascoe et al., 2003; Pascoe and Gréboval, 2003) and how this compares with fishing opportunities. Substantial research has also been undertaken on capacity adjustment, through regulatory or market-based approaches to achieve management objectives (e.g. MSY or MEY). This includes the design of buyback programs (e.g. Campbell, 1989; Holland et al., 1999, 2017; OECD, 2009, Holzer et al., 2017; Blomquist and Waldo, 2018), as well as the implementation of Individual Transferable Quota (ITQ) or other transferable fishing rights systems along with their potential benefits and limitations (e.g. Yandle and Dewees, 2008; Brinson and Thunberg, 2016; Pascoe et al., 2022; see topic VII). Factors influencing capacity, such as investment behaviour and capital (including fishing rights) ownership (Nøstbakken et al., 2011), entry and exit dynamics of fishing capacity in fisheries (Tidd et al., 2011), or technical progress in fisheries (Palomares and Pauly, 2019; Villasante and Sumaila, 2010) have also been extensively considered. This includes research into the specific implications of governmental support policies to the fishing sector on capacity, fish stocks and fisher welfare (e.g. [Clarke et al., 2005](https://doi.org/10.1016/j.jeem.2004.11.002); [World Bank, 2017](http://hdl.handle.net/10986/24056); Martini and Innes, 2018), where data limitations remain an issue.

In terms of decision-support, a range of established methodological approaches exist. These include the EU oriented capacity balance indicator guidelines which require an annual evaluation of several bio-economic indicators for (over)capacity of EU fleets[[15]](#footnote-16), leading to mandatory national plans to address excess capacity situations. Many other methodologies exist, such as the use of mathematical programming approaches (data envelopment analysis for capacity utilization) and statistical approaches (stochastic production frontiers for capacity utilization, regressions for fishing power, discrete-choice models to predict entry / exit behaviour). Bio-economic modelling (e.g. [Fishrent](https://fishrent.thuenen.de/), [FLBEIA](https://flbeia.azti.es/), [FishPEM](http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=TAD/FI(2018)2/FINAL&docLanguage=En), IAM) and approaches such as co-viability analyses (e.g. [Gourguet et al., 2013](https://doi.org/10.1016/j.fishres.2012.12.005)) have also been widely applied to the topic of capacity, and are being used in advice outside ICES, but less so within ICES. There is also a growing body of work detailing and retrospectively analysing experiences and lessons learnt from policies aimed at reducing capacity (e.g. [entry / exit scheme analysis](https://ec.europa.eu/fisheries/sites/fisheries/files/docs/body/201312-cessation-report_en.pdf)) and advising on evidence-based policy approaches for achieving sustainable fisheries (e.g. [OECD, 2000a](https://doi.org/10.1787/9789264188020-en), [2000b](https://doi.org/10.1787/9789264181182-en), [2006](https://doi.org/10.1787/9789264036581-en), [2007](https://doi.org/10.1787/9789264037960-en)).

## Data Limited Situations (on fleets and fish stocks)

Limitations to data affect the robustness of assessments on all aspects of fisheries management, be they biological, economic, technical or social (see e.g. ICES, 2021c). In the North Atlantic region, to which ICES pertains, the level of data covering all aspects of fisheries is at the highest globally. Indeed, the above four topics of applied fisheries economics research have developed with the increased availability of data regarding the costs and returns of fishing activities, in relation to the historically more readily available catch and effort data.

Nevertheless, for a number of species, stocks, fleets and fisheries the lack of data currently creates a significant problem in terms of effectively informing fisheries management. Limited data availability affects the quality and certainty of (i) single stock advice, where information on the activity and catches of certain fleets, including IUU activity, is unknown; (ii) mixed-fisheries management advice, where full assessments are not available for all the main stocks harvested; and (iii) incorporation of the effects of choke species, which adds uncertainty to the biological advice and the evaluation of management options (e.g. Hutniczak et al., 2019; Poos et al., 2018; ICES, 2020b; ICES, 2021c), including their economic and social consequences.

Data-poor conditions in the evaluation of fisheries and fleets have a variety of policy implications for the representation and management of sectors such as small-scale fleets, recreational fisheries and other marine users, as well as in assessing the significance of ecosystem services, and determining ecological, economic and social trade-offs underlying user-conflicts (Gacutan et al., 2019). Indeed, implications from the lack of economic data for evaluating economic efficiency tend to be greater where survey return rates are low, and estimation of fleet cost structure may not adequately reflect reality. In addition, economic data is generally reported at an annual time-step, which leaves important information that occurs at finer time scales unaccounted for (e.g. Curtin, 2021). Such limitations in data availability for example affect the analyses that can be carried out in support of the spatial and seasonal management of fishing activities, and the appropriate creation of fisheries management zones such as MPAs, temporary or permanent no-catch zones or other spatial measures designed to protect habitats, species and align fishing with other economic sectors (e.g. Ban et. al., 2009; Coccoli et. al., 2018; European Commission, 2018).

Given the prevalence of data-limited situations for both fishing fleets and fish stocks, including in the ICES area, growing efforts have focused on developing models and evaluation tools that enable assessing the ecological and economic outcomes and risks associated to exploiting these fisheries (see e.g. Pascoe et al., 2014; Rindorf et al., 2017; ICES, 2021c). Sensitivity analyses can evaluate how much the lack of knowledge impacts our understanding of the range of economic outcomes. Economic analyses can also help evaluate the importance of filling these data gaps, i.e. where should effort be spent in collecting additional information, according to a range of outcomes relevant to livelihoods, profits, etc. Nielsen et al. (2018b) reviewed this research, considering the accessibility of models and their development to ensure widespread and open access availability, user-friendly model operation, and efficient widespread adoption and implementation by a diversity of stakeholders.

## Shared stocks management

Managing the exploitation of [shared fish stocks](http://www.fao.org/3/y5438e/y5438e05.htm)[[16]](#footnote-17) to ensure biological sustainability as well as utilisation in a way that provides greatest societal benefit remains a significant and elusive challenge. A number of related fisheries management questions arise, as independent parties often do not agree on what issues to prioritize in the management of a shared stock given the differing economic, social and environmental situations that countries and their respective fleets face. Perceptions of where the greatest societal benefit lies may differ, for example the optimal decision for one party may be immediate consumption while for the other it is investment. For this reason, negotiating a common approach to managing a shared fishery is challenging, with complexity increasing substantially with the number of participants (Villasante et al., 2014).

The shared nature of stocks adds a level of complexity on top of other topics in fisheries management such as TAC setting, mixed-fisheries management, marine spatial planning, capacity regulation and rights allocation. Determining and advising on the biologically appropriate total level of catch (i.e., TAC) for a shared stock generally requires much the same information and methods of assessment as stocks that are not shared. Country-level factors, including strategic and political aspects, as well as industry-level factors mean mismatches can occur, resulting in significant differences in incentives for cooperation and uptake of management decisions in the fisheries, potentially reducing the stability of any agreements. These are issues that have become further complicated and strained by range shifts, where some shared stocks have moved (or are expected to move) across geographical boundaries, due e.g. to climate-related change in ecosystems (Hannesson, 2012; Bjørndal et al., 2004; Kaiser et al., 2018).

At present, ICES routinely undertakes assessments to determine reference points and advise on the setting of TACs for shared stocks, from the biological perspective (e.g. NE Atlantic mackerel). The international component of such decisions, how this influences the TAC that is actually implemented, and the subsequent need to allocate quotas (which can feed back to the TAC setting process) is however not explicitly accounted for in ICES analysis or advice.

Economic analysis can play a key role in identifying and assessing the factors influencing how a TAC is ultimately set and distributed, the outcomes of this allocation in terms of actual fishing mortality and associated economic and social impacts, and possible alternative scenarios ([Bailey et al.](https://www.sciencedirect.com/science/article/pii/S0308597X12002552), [2013](https://www.sciencedirect.com/science/article/pii/S0308597X12002552); [Lazkano et al., 2013](https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1939-7445.2012.00138.x)). Using a structured method of analysis to incorporate and systematically assess the alternative outcomes and trade-offs of changes to key factors of influence, i.e. scenario analysis, can be an effective way of refining management strategies and mitigating the risk of poor outcomes.

Indeed, topics associated with shared stock management have been the focus of substantial economic work in research groups and organizations that are heavily involved in ICES and elsewhere. These efforts have mostly been devoted to understanding outcomes from the fishery perspective in a single-stock, TAC-based, setting. Extensive modelling work has been undertaken on the subject of quota allocation, following a TAC being set, and the implications of different allocation regimes. Standardised methodologies exist to analyse the impacts and trade-offs of different management options, and when sufficient data is available multiple objectives can be considered, utilising approaches such as goal programming and game theory to consider strategic behaviour ([Hannesson, 2011](https://www.annualreviews.org/doi/10.1146/annurev-resource-083110-120107)). Integrated scenario analyses, models for the explorative forward-looking simulation of various scenarios, over both the short and long-term, also exist and can explore normative scenarios (MSY, MEY, co-viability targets such as in [Curtin et al., 2013](https://onlinelibrary.wiley.com/doi/abs/10.1111/cjag.12009)). Some research from a less fishery-centric perspective has also been undertaken, such as that focusing on bycatch and discards, and the multiple objectives of contracting parties, industry stakeholders, fishing communities and/or environmental NGOs (see e.g. Lane, 2008; [Lent and Squires, 2017](https://www.mmc.gov/wp-content/uploads/RLent-Bycatch-Economics-Paper.pdf)).

## Fishing rights allocation

Fishing rights, in particular quota allocation is a key foundation of many fisheries and their management in ICES member countries. In many ways, it represents the interplay between traditional ICES biological advice, centered on identifying sustainable targets and limiting fishing mortality levels, and the policy practicalities of how management bodies actually implement that advice. This interplay runs both ways, with biological advice affecting the TAC to be allocated, with ensuing social and economic implications at multiple scales, while the ways in which fishing rights are allocated and used also has feedback loops to the scientific advice. Economics can play a key role in helping understand this interplay, especially in relation to the political economy of converting science advice into fishing opportunities (Bellanger et al., 2016).

Currently, questions relating to the process by which fishing rights are allocated among individual fishers are not included in the research undertaken by ICES or the advice it produces. However, currently strong scientific expertise exists and an active research effort is being undertaken in ICES countries on the economic analysis of this topic, including by research groups and organizations that are also strongly involved in ICES. Examples include the guidance established by organizations such as OECD (2006) on the use of market mechanisms to allocate fishing rights, or [NOAA](https://media.fisheries.noaa.gov/dam-migration/01-119-02.pdf) (2016) on best-practice allocation of quota, which rely on economic analysis of the key questions at play in designing such systems[[17]](#footnote-18), as well as retrospective studies evaluating national programs, such as Hoefnagel and de Vos (2017) for the Netherlands or Pascoe et al. (2022) for Australia. Research has also focused on reviewing the impacts of various types of rights-based management approaches (see e.g. Shotton, 2001; Costello et al., 2008; Thébaud et al., 2012).

In particular, there has been a growing number of studies that specifically investigate the differences between individual (tradeable/non-tradeable) and collective (quota pools, cooperatives, etc.) allocations. The core questions considered in these analyses relate to the description of how quota is being allocated, and the analysis of impacts that changes in allocation mechanisms could have on overall economic efficiency (e.g. evaluation of potential economic returns under alternative scenarios using bio-economic modeling), social impacts and distributional aspects, including issues relating to rent capture. A growing area of research relates to the question of allocating quota between different sectors, in particular between recreational and commercial fishing (e.g. Holzer and McConnell, 2014; Lee et al., 2017; Tidbury et al., 2021).

As data on quota holdings and trading prices become increasingly available, applications of economic theory aiming to quantify existing economic returns and how they have or could be captured by different parties to the fisheries are feasible, as well as how this may facilitate capacity adjustment (Topic IV). There is still limited information on the lease and sale prices of quotas, which in some case are traded in a bartering system (so-called “quota swapping” where quotas of some stocks are exchanged for quotas of other stocks, see Hoefnagel et al., 2015 or Holland et al., 2015). However, cost and earnings data on commercial fishing operations can be used to estimate economic returns associated with fishing rights (see e.g. Gardner et al., 2015), although such estimations have not commonly been carried out.

## Sustainability of Small-Scale Fisheries

Historically, limited research and advice regarding the economic status and importance of Small-Scale Fleets (SSF) has been available in developed countries, while being more common in developing countries. Indeed, the perception by policy makers that these fleet segments were of limited economic and ecological relevance in developed countries, led to a lesser research effort on these fisheries (Guyader et al., 2013). Lately, with growing interests regarding the economic, social and ecological impacts of the SSF by different stakeholders[[18]](#footnote-19), the knowledge base as well as quantity and quality of available data has been improving. Besides standardized data collection at national and international scale, surveys, or innovative/experimental methods have increasingly been applied to complement existing data (e.g. Nassiri et al., 2021). This research focuses in particular on cases where coastal communities depend on SSF, and on their adaptations to changing markets, ecosystems as well as institutional and management contexts (Guyader et al., 2013; Finkbeiner, 2015; TBTI, 2016; Wakamatsu and Wakamatsu, 2017; Chuenpagdee and Jentoft, 2019; Drury O’Neill et al., 2019; Frawley et al., 2019; Leopold et al., 2019; Prosperi et al., 2019; Young et al., 2019; Pascual-Fernández et al., 2020; Murillas-Maza et al., 2021). Research has also aimed to evaluate cultural ecosystem services including heritage, tourism etc. (Durán et al., 2015; Le Gallic et al., 2015; Garcia Rodrigues et al., 2017; Ropars-Collet et al., 2017; Andersson et al., 2021) provided by SSF to coastal regions[[19]](#footnote-20). SSF tend to operate in areas in high demand for other sectors (e.g. recreational activities, aquaculture, renewable energy, coastal development) which often leads to spatial conflicts (Gimpel et al., 2015). Additionally, some of the fish stocks exploited by SSF are also in high demand by the recreational sector (Lee et al., 2017; Tidbury et al., 2021). Driven by these conflicts and the resulting need for management (e.g. through marine spatial planning and/or quota allocation) and management evaluation, a growing body of data and analyses is becoming available, including with approaches and methods relating to data-poor situations (see topic V). There is also on-going discussion regarding the definition of SSF, in particular compared to recreational fisheries (see also topic X; García-Flórez et al., 2014; Hyder et al., 2018). While this research is not explicitly included in the scope of ICES science and advice, results from these analyses are increasingly being considered in the work of some of its working groups, such as via the inclusion of information on fisheries dependent communities in integrated ecosystem assessments (including via the use of fishery dependency information, e.g. Carvalho et al., 2017 in the EU), or through the evaluation of the cultural ecosystem services associated with coastal fisheries (see topic XII).

## Links between catch sector and markets for fish

Fishing is not only about catching fish, but also about its processing and sale, creating added-value at various scales from the coast to entire supply chains extending nationally and internationally, thereby generating welfare and wealth in society. The importance of understanding the links between the catch-sector and markets for fish is increasingly being acknowledged, especially as seafood belongs to the most highly traded food commodities internationally (Smith et al., 2010; Watson et al., 2017). The operations of markets and value chains for seafood thus often mediate the impacts of fisheries management.

At this point in time, there is no research conducted on the link between the catch sector and the market for fish within ICES, despite data being collected by various organizations across ICES and internationally. Research currently practiced external to ICES has mostly focused on describing markets for fishery products and the associated supply chains. In some countries, the effects of commercial fishing management systems on welfare and the wider economy have been investigated. Methods and tools used to carry out such analyses of management effects on the wider economy include impact and input/output analysis. Some modelling work has also sought to combine bio-economic models of fishing with models of international trade in fish products (e.g. Mullon et al., 2009). While in general, it can prove difficult to disentangle the effects of management measures from the effects of trade on markets for seafood, a growing number of studies have considered this question (e.g. Birkenbach et al., 2017). In the last twenty years, studies have also increasingly considered the effects of eco-labelling and fisheries certification schemes on production systems and/or fishers’ behaviour (Roheim et al., 2018) and on seafood consumer behaviour, trying to understand consumers expectations and preferences or willingness to pay for “eco-friendly” seafood (Ankamah-Yeboah et al., 2020; Menozzi et al., 2020).

For fish market and demand, traditional quantitative tools such as supply/demand curve estimations, inverse demand models, co-integration as well as hedonic price models are regularly used. Qualitative tools like focus groups are also used for consumer perception analysis. Data and parameters available for fish market studies include first sales (ex-vessel) data (e.g. in Europe data produced under the Data Collection Framework[[20]](#footnote-21), information collected by the European Market Observatory as well as domestic and foreign trade statistics). However, these data often do not contain enough detail for larger range market analysis (for example, they often miss important attributes such as buyers' identifying characteristics, enabling cross referencing and data aggregation). In addition, value chain analyses are generally based on national data, however their consistency and coverage at international level are still to be developed (STECF, 2019). Consumer and demand analysis require implementation of ad hoc data collection at national level, with the risk of inconsistencies between studies of being rapidly outdated due to changing market conditions.

## Diversification of commercial fishing

Diversification in commercial fisheries refers to economic strategies aimed at increasing net returns and managing risks associated with fishing activities. Diversification operates at the scale of individual fishers, fishing firms as well as coastal communities. The underlying economic drivers relate to economies of scale (lowering production costs as the scale of production grows bigger), economies of scope (lowering production costs by diversifying products), as well as portfolio effects (reducing variation of returns by combining a diversity of assets). In fisheries, subject to variable levels of technical, economic and institutional constraints, diversification may involve expanding the range of activities to other sectors, such as tourism or processing (Conejo-Watt et al., 2021; Miret-Pastor et al., 2020; Morgan, 2016), or to multiple fishing operations, such as using multiple gears to target different species (Briton, et al., 2021; Gonzalez-Mon, et al., 2021; Kasperski and Holland, 2013). Firms may also seek to engage in multiple levels of the fish supply chain, for example fishing companies investing in the processing sector (Nøstbakken et al., 2011), or processors seeking control of the catch operations (Edwards and Pinkerton, 2019). Diversification may provide important economic benefits in the face of major external drivers such as ecological changes resulting from global warming, or the impacts of disruptions in supply chains due to sanitary crises.

As already discussed (see topic II), diversification of fishing operations within the fishery generates important questions regarding the coordination of management measures that are set for different sectors of the fishery, as their effectiveness will be affected by responses of fishers across the different sectors. More generally, the different forms of diversification have implications for fisheries management since they will alter the incentives driving fishing behaviour, in particular the opportunity costs of fishing – for example, fishers might be less willing to engage in fishing activities during periods with high earnings outside the fishing sector.

Economic research has used a wide range of mathematical and statistical methods to examine diversification strategies, their impacts on incentives and the implications for fisheries management. Bio-economic models have also been used for identifying advantages of alternative diversification strategies (Gourguet et al., 2014; Nielsen et al., 2018a; Solís, et al., 2020;). Data for within-fisheries analyses, such as fishing effort, gear use and catch composition, is frequently available in developed countries, while data for diversification outside the fishing sector is not collected on a regular basis. To date, despite its importance in understanding the responses of fisheries to management, this research is not regularly incorporated in fisheries management advice, internationally.

## Fisheries-aquaculture connections

Marine aquaculture has grown steadily over the past decades, and provides a growing contribution to global food security (Costello et al., 2020). Fisheries and aquaculture have a wide array of interactions beyond the biological interactions of genetic, restocking and disease, which are already being considered by ICES[[21]](#footnote-22). Economic research has considered the structure and quantification of interactions between the two sectors, throughout the seafood value chain and beyond (Mikkelsen et al., 2020). Examples of these interactions include competition for space between fishing and aquaculture, which can be addressed by marine spatial planning (Outeiro et al., 2020; Lester et al. 2018; Gimpel et al., 2018). The fishing sector also provides raw materials for aquaculture in the form of feed, seed, fry or fingerlings (Natale et al., 2013; Kamermans and Capelle, 2019). Larger fish, such as tuna or cod, are caught for capture-based aquaculture (CBA). Importantly, market interactions at local and international levels between wild and farmed species can influence fish prices and, consequently, fishers and farmers incentives and strategies (Anderson, 1985; Jensen et al., 2014; Valderrama and Anderson, 2010; see also topic IX). Moreover, fisheries firms can learn from the efficiency gains obtained in the aquaculture sectors, regarding product development, distribution and markets (Asche et al., 2007). Finally, aquaculture and fisheries can provide alternative sources of employment for coastal communities and a complementary source of food for the world population. Research on the social and economic dimensions of aquaculture development has steadily developed over the past two decades, including within ICES[[22]](#footnote-23). However this work has not yet specifically considered the economic interactions between fisheries and aquaculture.

## Ecosystem Services Valuation

Fisheries and aquaculture provide provisioning and cultural ecosystem services (ES), aspects of ecosystems that are utilized to produce human well-being (MEA, 2005). Through their interactions with ecological components and functioning, they also affect other supporting and regulating services provided by marine ecosystems. Economic assessment of ES is usually applied in the context of ecosystem-based approach to fisheries management (EBFM) (ICES, 2005; Link, 2004; Murawski, 2007) and when competing interests in the exploitation of the marine resources require Maritime Spatial Planning (MSP) (Directive 2014/89/EU). An extensive range of methods and tools are available to assess the total economic value of the different ES provided by marine ecosystems (e.g. Tietenberg and Lewis, 2012; Bateman et al., 2002, 2011; Custodio et al., 2019). While spatial analysis (including GIS, spatial statistics or network analysis) is used to support MSP (Gacutan et al., 2019), multi-criteria analysis can be used to explore the trade-offs between multiple objectives when less comparable data is available.

Several widely accepted ES classification systems exist nowadays including the Common International Classification of Ecosystem Services (CICES)[[23]](#footnote-24) adopted by the European working group on Mapping and Assessment of Ecosystem Services (MAES) or the UK National Ecosystem Assessment, which provide a framework for ICES to work upon. A range of economic data are now available on ES (e.g., de Groot et al., 2020), from standardized carbon accounting datasets at a national level to point estimates of ES in particular locations. However, wide-ranging internationally comparable datasets of the monetary or non-monetary value of ES across countries do not currently exist. National accounts provide information widely on provisioning ES, but in some instances also data on specific cultural ES (La Notte et al., 2017). Efforts to progress these data are being supported as part of broader initiatives to establish reporting standards on the blue economy (see e.g. Addamo et al., 2021; Jolliffe et al., 2021)

Current research external to ICES focuses on the link of marine ES to human wellbeing of coastal communities (IISD, 2011; MEA, 2003; MEA, 2005). This includes the importance and limitations of scale and transferability when looking at specific ES studies in assessing and monetising ES as well as integrating these approaches into environmental impact assessments and multi-criteria analysis. Key questions under study relate to understanding human impacts on ES, to help foster behavioural changes (Knights et. al., 2013; HELCOM, 2010; Halpern et. al., 2008), as well as understanding of the potential for nature-based solutions to restoring ES. This research underpins, for example, policies on spatial planning (e.g., Welsh National Marine Plan), the Natural Capital approach (e.g., UK’s 25 years Environmental Plan, UN’s SEEA) or Blue Growth policies (e.g., OECD’s Ocean Economy 2030 report). Thereby, special consideration is given to the trade-offs between different ES within or across different systems and their relation to policy objectives (Chícaro et. al., 2015). Limitations in the use of economic valuation by policy-makers has also been developing (Marre et al., 2016).

Research on the understanding and Valuation of ecosystem services is currently being pursued in several ICES working groups. The Working Group on Resilience and Marine Ecosystem Services (WGRMES) has been developing quantitative and qualitative methods to map, assess and evaluate the contribution of marine ecosystem services to human well-being in European ecoregions, in collaboration with the Ecosystem Services Partnership. WGRMES already provided a global data repository on existing marine and coastal cultural ES. The Working Group for Marine Planning and Coastal Zone Management (WGMPCZM) has developed the concept of culturally significant areas, and proposed pilot applications of this concept. Other groups focusing on aquaculture[[24]](#footnote-25) and biodiversity science[[25]](#footnote-26) have also been considering the use of ecosystem services assessment as part of their work.

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# B – Topic coordinators and reviewers

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| --- | --- | --- | --- |
| Topic number | Topic description | Topic coordinators | Topic reviewers |
| 1 | Total Allowable Catch (TAC) setting in output-based management systems | Arina Motova, Jarno Virtanen | Claire Macher, J. Rasmus Nielsen, Raul Prellezon, Renato Rosa |
| 2 | Mixed and multi-species fisheries management | J. Rasmus Nielsen, Renato Rosa | Angela Muench, Claire Macher, Katell Hamon, |
| 3 | Area-based and spatial management | François Bastardie, Renato Rosa | James Innes, Katell Hamon, Peter Greene |
| 4 | Adjustment of capacity to resource potential | James Innes, Jarno Virtanen | Arina Motova, Raul Prellezo |
| 5 | Data Limited Situations (on fleets and fish stocks) | Arantza Murillas, J.Rasmus Nielsen | Gustav E. Blomqvist, Ralf Doering, Sakari Kuikka |
| 6 | Shared stocks management | James Innes, Olivier Thébaud | Alan Haynie, Juan José García del Hoyo |
| 7 | Fishing rights allocation | Olivier Thébaud, James Innes | Hazel Curtis, Jarno Virtanen, Peter Greene |
| 8 | Sustainability of small-scale fisheries | Gustav Enhol Blomqvist, Fabienne Daurès | Staffan Waldo, Arantza Murillas, Angela Muench |
| 9 | Links between catch sector and markets for fish | Fabienne Daurès, Gustav Enhol Blomqvist | José Luis Santiago Castro-Rial, Peter Greene, Rasmus Nielsen |
| 10 | Diversification of commercial fishing | Staffan Waldo, Leyre Goti | Rasmus Nielsen, Gustav Enhol Blomqvist, Fabienne Daurès, David Castilla Espino, Arina Motova |
| 11 | Fisheries-aquaculture connections | Staffan Waldo, Leyre Goti | Rasmus Nielsen, Gustav Enhol Blomqvist, Fabienne Daurès, David Castilla Espino, Arina Motova |
| 12 | Ecosystem services evaluation | Angela Muench, Sebastian Villasante | Arantza Murillas, David Castilla Espino, Peter Greene, Leyre Goti |

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16. See <http://www.fao.org/3/y5438e/y5438e05.htm> for a definition. [↑](#footnote-ref-17)
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18. See e.g. Said and Chuenpagdee (2019) and <https://ec.europa.eu/oceans-and-fisheries/fisheries/rules/small-scale-fisheries_en> for the European context. [↑](#footnote-ref-19)
19. See e.g. the projects Cabfishman (<https://www.cabfishman.net/>) and DiadES (<https://diades.eu/>). [↑](#footnote-ref-20)
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21. https://www.ices.dk/community/groups/Pages/Wgagfa.aspx [↑](#footnote-ref-22)
22. https://www.ices.dk/community/groups/Pages/WGSEDA.aspx [↑](#footnote-ref-23)
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